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(54) **METHODS AND SYSTEMS FOR PRESENTING EN ROUTE DIVERSION DESTINATIONS**

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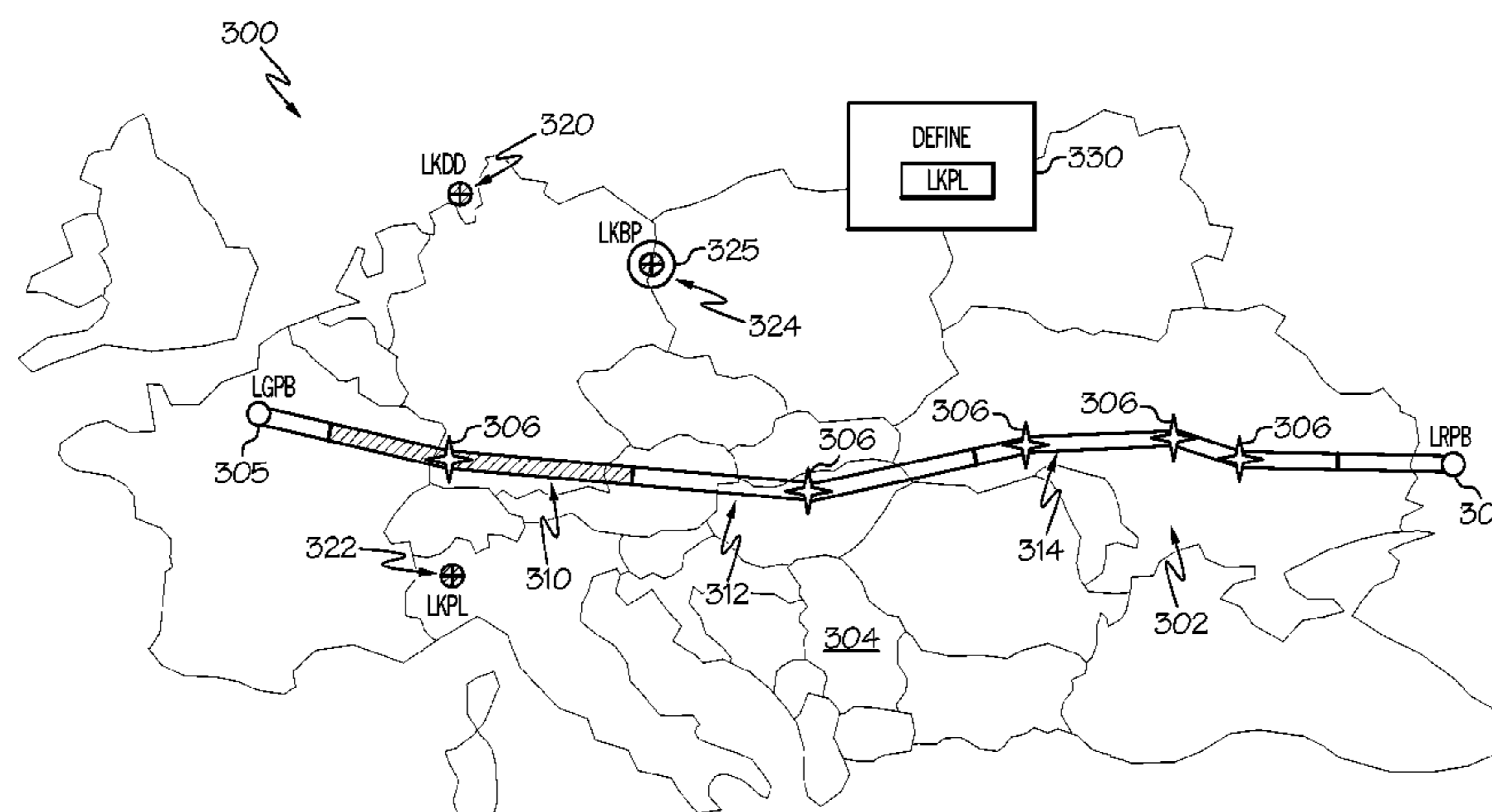
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(57) **ABSTRACT**

Methods and systems are provided for indicating suggested or recommended diversion destinations with respect to segments of a planned route of travel. One exemplary method of presenting potential diversion airports for an aircraft involves identifying a flight path segment of a plurality of flight path segments between a departure location and a destination location based on a flight plan from the departure location to the destination location and identifying a subset of airports satisfying one or more filtering criteria with respect to the flight path segment. From among that subset, a recommended diversion airport is identified based on a viability ranking of the subset of airports with respect to the flight path segment and indication of the recommended diversion airport for the flight path segment is provided to a pilot or other user.

20 Claims, 8 Drawing Sheets



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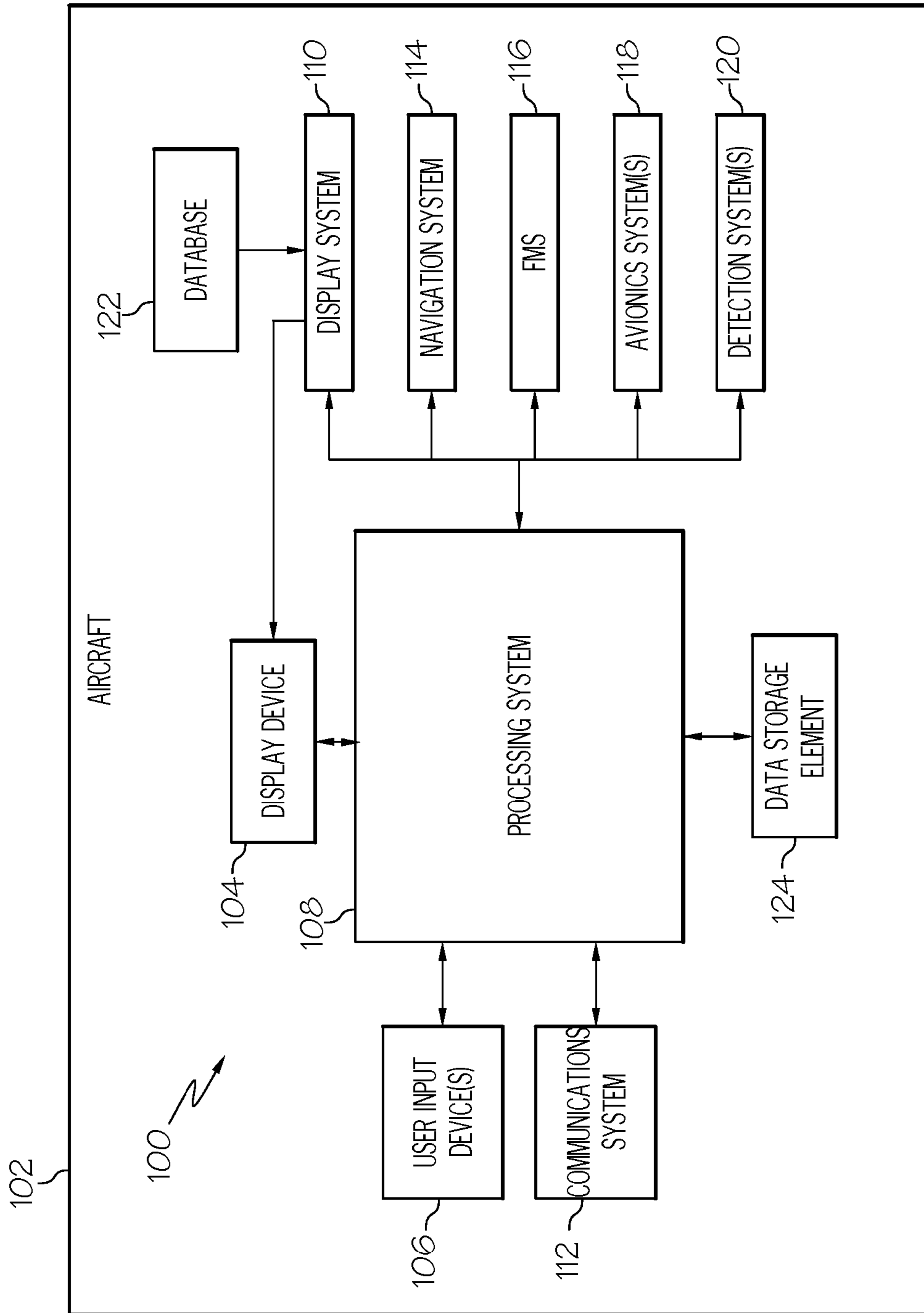


FIG. 1

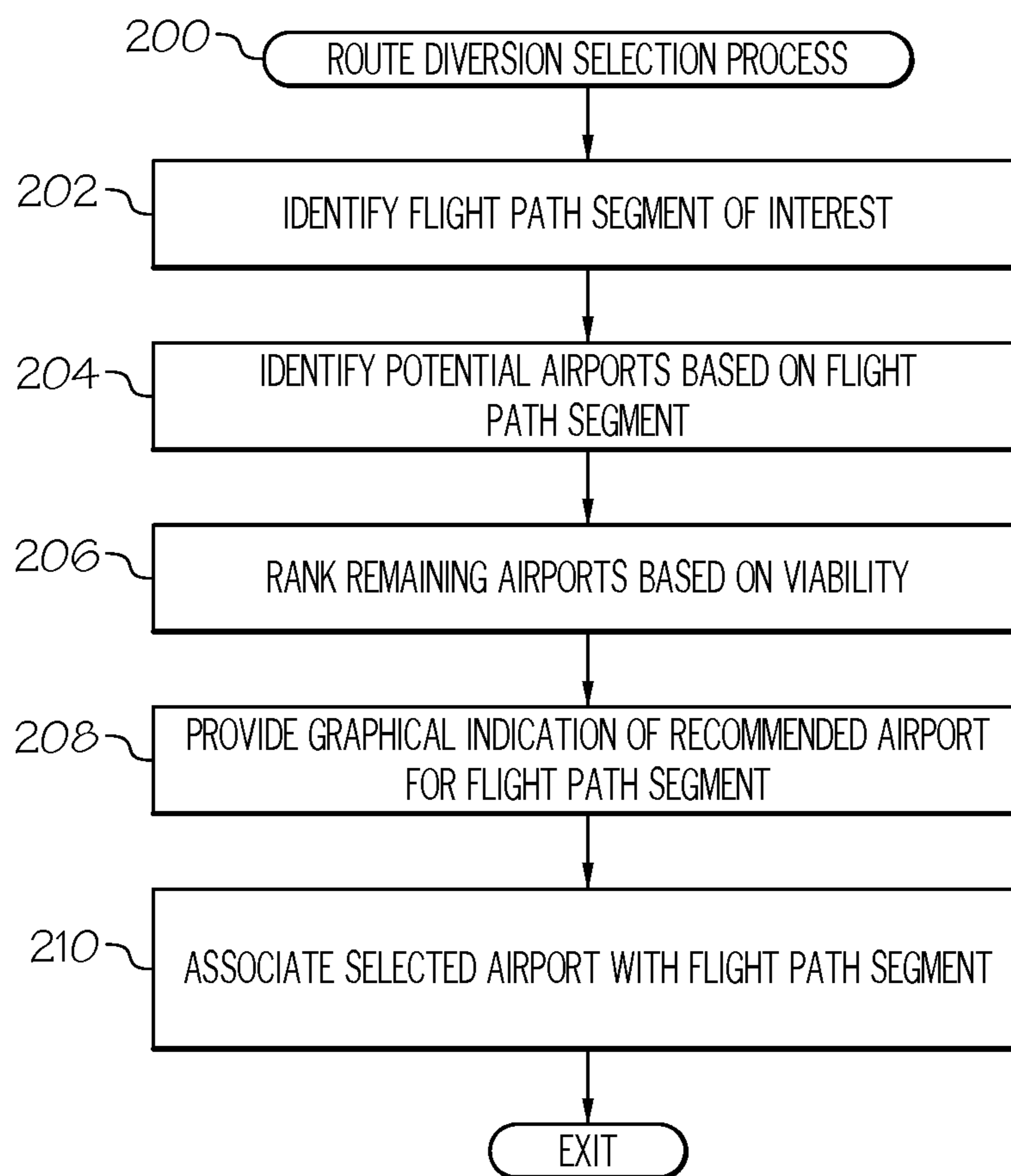


FIG. 2

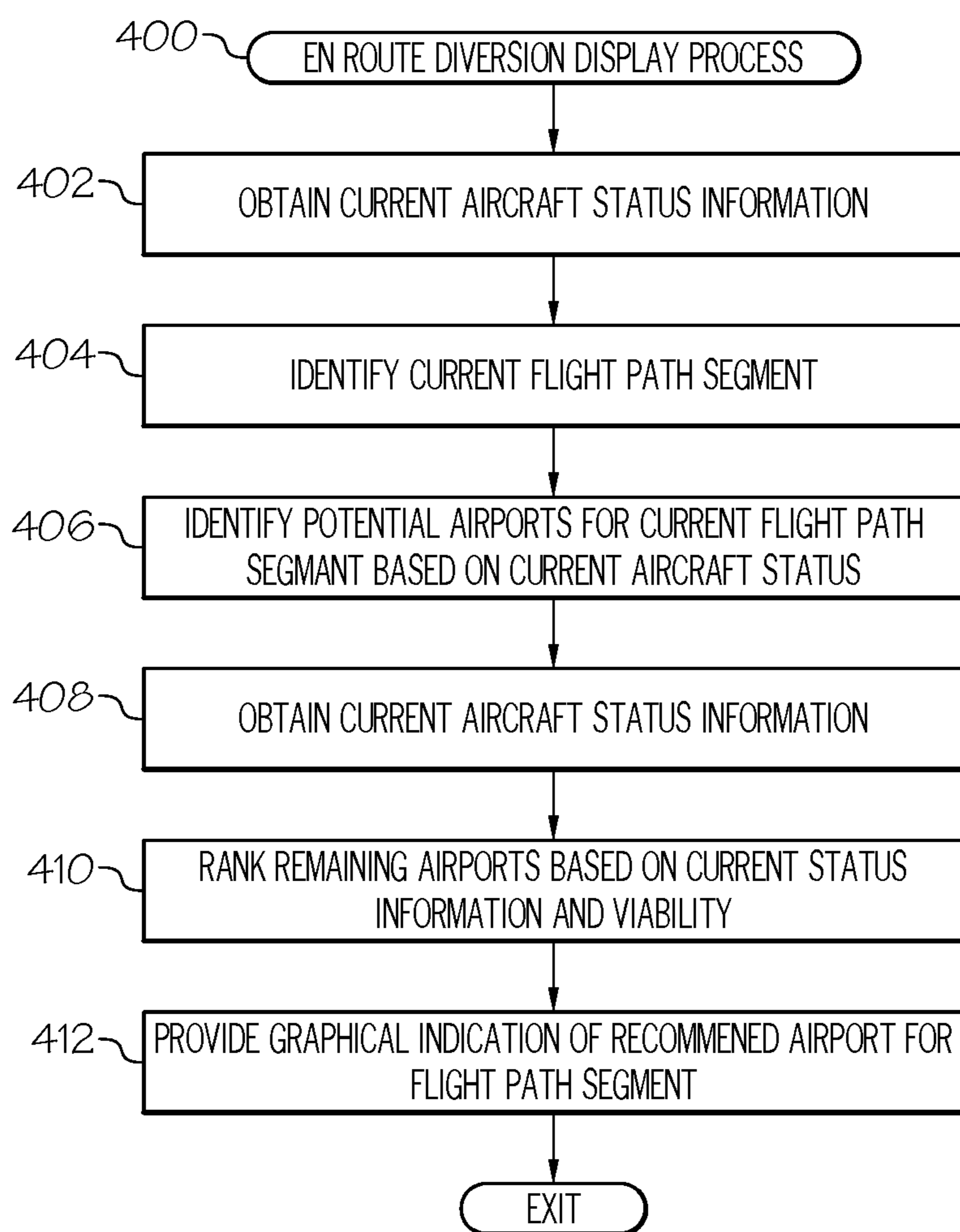


FIG. 4

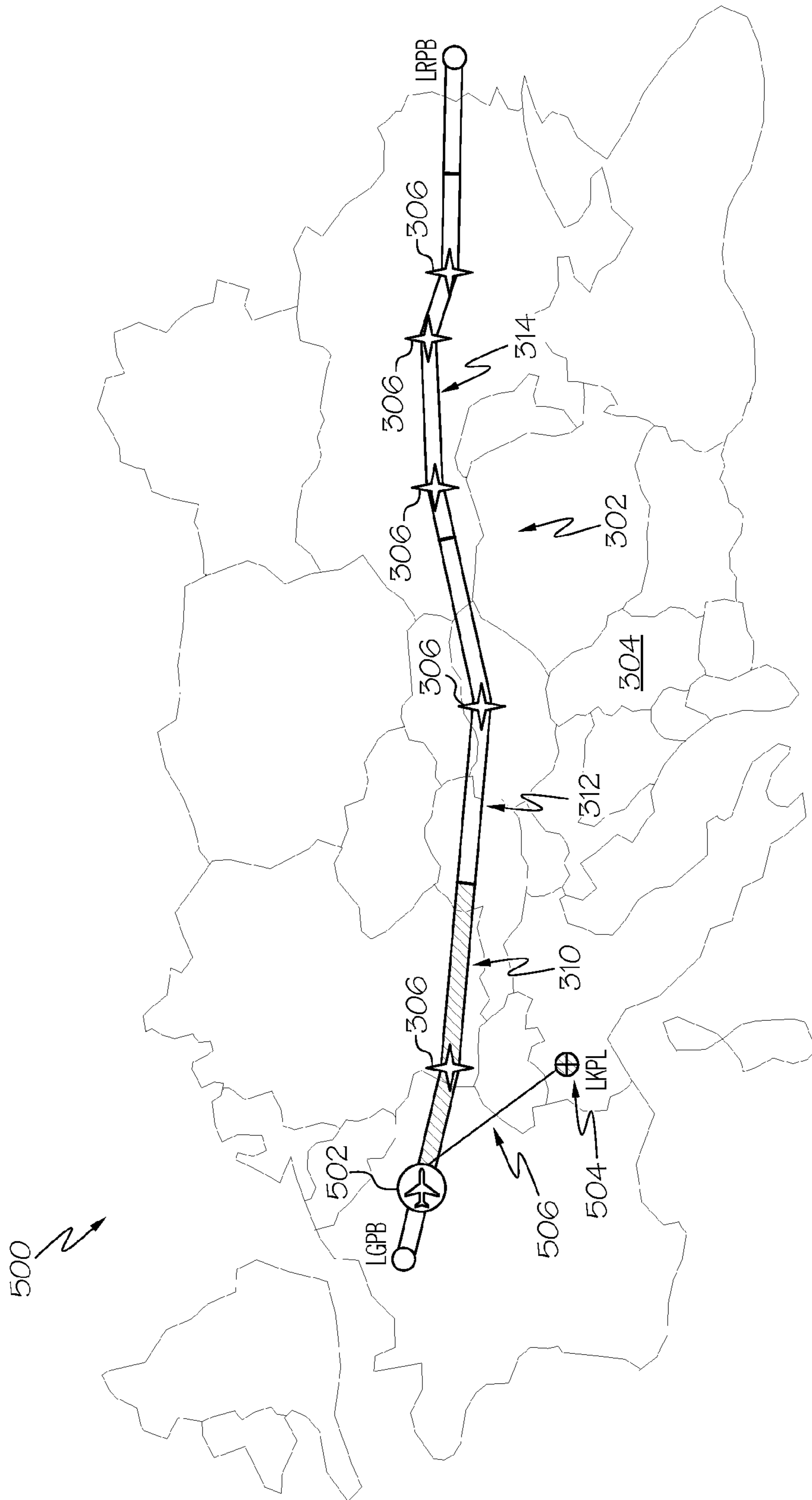


FIG. 5

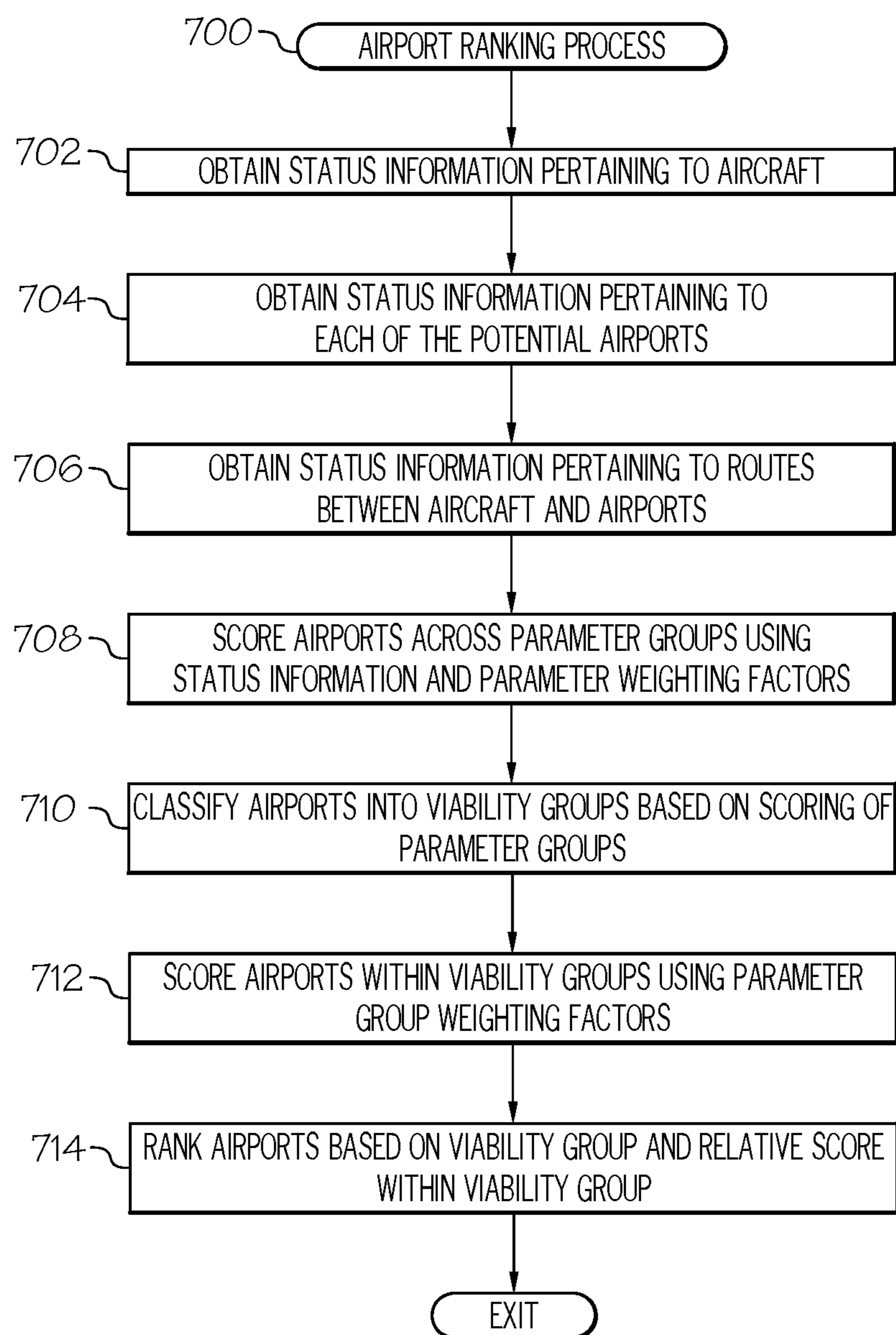


FIG. 7

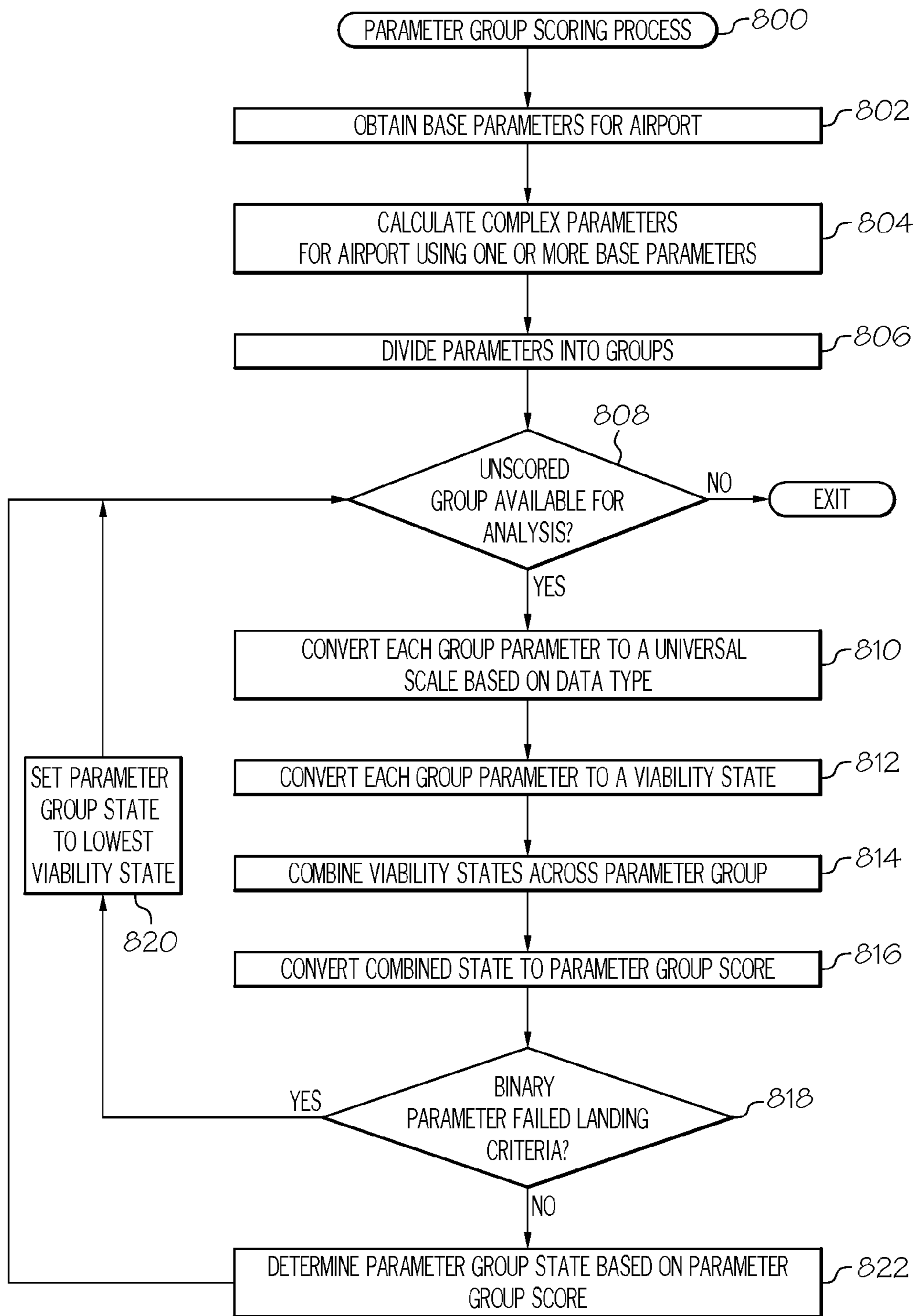


FIG. 8

1**METHODS AND SYSTEMS FOR
PRESENTING EN ROUTE DIVERSION
DESTINATIONS**

TECHNICAL FIELD

The subject matter described herein relates generally to vehicle display systems and related human factors, and more particularly, embodiments of the subject matter relate to aircraft systems capable of reducing a pilot's workload and improving the pilot's situational awareness when selecting en route diversion or alternate airports.

BACKGROUND

Pilots, air traffic controllers, airline personnel and the like routinely monitor meteorological data, reports, and forecasts to assess any potential impacts on the current or anticipated flight plan and the intended destination. However, in situations where the aircraft needs to deviate from the original plan, such as an emergency situation, the information needs to be reanalyzed with respect to the deviation to facilitate continued safe operation. For example, in the case of an emergency landing, ideally a pilot would select an airport within range of the aircraft where landing is least likely to be compromised or complicated by weather or other factors. This requires consideration of numerous pieces of information (e.g., fuel remaining and distance to be traveled, weather radar and/or forecast information, NOTAMs, SIGMETs, PIREPs, and the like), which often is distributed across different displays or instruments, requiring the pilot to mentally piece together all the different information from the different sources. Additionally, in the case where the information for the first airport analyzed discourages landing there, the pilot must repeat the task of aggregating and analyzing the information for one or more additional airports.

In some situations, during pre-flight briefing, a pilot may desire to preselect alternate or diversion airports along the flight plan for potential use en route to the destination. While the foregoing demands of mentally piecing together different information from different sources persists, the pilot must also analyze the information with respect to locations along the flight plan. Moreover, once en route, the viability of a preselected alternate may change without the pilot's awareness. Thus, in the event of an emergency, due to the mental stress and exigent nature of operation, the pilot may revert to a preselected airport that is suboptimal or less viable than when originally selected. To remedy the situation, the pilot is again faced with the task of reanalyzing the different information from different sources during an emergency situation, which further increases the pilot's workload. Accordingly, it is desirable to reduce the mental workload of the pilot (or air traffic controller, or the like) when analyzing and selecting alternates en route to a destination.

BRIEF SUMMARY

Methods and systems are provided for presenting potential diversion destinations for a vehicle, such as an aircraft. One exemplary method of presenting potential diversion airports for an aircraft involves identifying a flight path segment of a plurality of flight path segments between a departure location and a destination location based on a flight plan from the departure location to the destination location, identifying a subset of airports satisfying one or more filtering criteria with respect to the flight path segment,

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identifying, from among the subset, a recommended diversion airport based on a ranking of respective airports of the subset of airports according to the respective viability associated with each respective airport of the subset of airports with respect to the identified flight path segment, and providing an indication of the recommended diversion airport associated with the flight path segment.

An apparatus for a vehicle system is also provided. The system includes a display device onboard a vehicle, a data storage element maintaining information defining a segment of a travel plan, a communications system onboard the vehicle to obtain status information for a plurality of destinations, and a processing system coupled to the communications system, the data storage element, and the display device. The processing system is configured to determine viability associated with respective destinations of the plurality of destinations with respect to the segment based on at least in part on the status information for the respective destinations, identify a recommended diversion destination from among the plurality based on a ranking of the respective destinations according to the viability, and provide an indication of the recommended diversion destination associated with the flight path segment on the display device.

Another embodiment of a method of presenting potential diversion destinations for a vehicle involves a processing system onboard the vehicle identifying a segment of a plurality of segments of a route between a departure location and a destination location, obtaining status information associated with one or more locations along the segment, obtaining status information associated with each of a plurality of alternate destinations, determining viability scores for each of the plurality of alternate destinations with respect to the segment based at least in part on the status information associated with the one or more locations along the segment and the status information associated with the respective alternate destination location, identifying a recommended alternate from among the plurality of alternate destinations based on a ranking of respective alternate destinations according to the viability scores associated with the respective alternate destinations, and providing an indication of the recommended alternate associated with the segment on a display device onboard the vehicle.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the subject matter will hereinafter be described in conjunction with the following drawing figures, wherein like numerals denote like elements, and:

FIG. 1 is a block diagram of a system for an aircraft in an exemplary embodiment;

FIG. 2 is a flow diagram of an exemplary route diversion selection process suitable for use with the aircraft in the system of FIG. 1 in accordance with one or more embodiments;

FIG. 3 depicts an exemplary navigational map display suitable for display on a display device associated with the aircraft in the system of FIG. 1 in accordance with one or more embodiments of the route diversion selection process of FIG. 2;

FIG. 4 is a flow diagram of an exemplary en route diversion display process suitable for use with the aircraft in the system of FIG. 1 in accordance with one or more embodiments;

FIGS. 5-6 depict exemplary navigational map displays suitable for display on a display device associated with the

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aircraft in the system of FIG. 1 in accordance with one or more embodiments of the en route diversion display process of FIG. 4;

FIG. 7 is a flow diagram of an exemplary airport ranking process suitable for use with the route diversion selection process of FIG. 2 or the en route diversion display process of FIG. 4 in accordance with one or more embodiments; and

FIG. 8 is a flow diagram of an exemplary parameter group scoring process suitable for use with the airport ranking process of FIG. 7 in conjunction with the route diversion selection process of FIG. 2 or the en route diversion display process of FIG. 4 in accordance with one or more embodiments.

DETAILED DESCRIPTION

Embodiments of the subject matter described herein generally relate to systems and methods for intelligently presenting potential diversion destinations to a vehicle operator in a manner that reduces workload while improving situational awareness with respect to an otherwise complex situation. For example, a pilot looking to divert from an originally scheduled flight plan and land the aircraft may be faced with numerous potential landing locations (e.g., airports, landing strips, and the like), with each being associated with its own unique set of factors or current circumstances that may make that location more or less suitable for landing the aircraft, while also having to account for the current operations of the aircraft (and any operational concerns associated therewith). While the subject matter is primarily described herein in the context of presenting potential diversion airports for an aircraft looking to deviate from a flight plan, the subject matter described herein may be similarly utilized in other applications to deviate from a predefined route for travel (e.g., a travel plan or travel route) or with another vehicle (e.g., automobiles, marine vessels, trains). That said, for purposes of explanation, but without limitation, the subject matter is described herein in the context of presenting information pertaining to aircraft operations. Additionally, it should be noted the subject matter is not necessarily limited to vehicle operators and may be utilized by dispatchers, air traffic controllers, or other users, as appropriate.

As described in greater detail below in the context of FIGS. 2-3, in exemplary embodiments described herein, the flight plan is subdivided or segmented into a number of segments between departure and destination locations, with diversion destinations being analyzed and presented with respect to each segment. In this regard, for a particular flight path segment, potential diversion destinations are scored, graded, or otherwise quantified in terms of their respective viabilities with respect to the entire length or duration of the flight path segment to be flown by the aircraft. Thus, in exemplary embodiments, the potential diversion destinations to be analyzed may be initially filtered based on their distance from one or more locations along the segment (e.g., in terms geographic distance, flight time, or the like) or other filtering criteria to limit the scope of the analysis to a limited number of realistic or feasible potential destinations.

Stated another way, each flight plan has a plurality of segments for which alternate or diversion destinations may be defined. Based on various criteria, as to be discussed below, the processing system determines a limited subset of airports capable of being an acceptable diversion destination associated with a particular flight plan segment. Airports among this subset are then analyzed in terms of their viability and the most viable airport may be indicated as

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recommended or preferable and presented on a display associated with the aircraft to reduce pilot workload in identifying a desired alternate destination for a flight plan segment.

After filtering the potential diversion destinations to be analyzed with respect to a flight path segment, the remaining potential diversion destinations within the filtered subset are scored, graded, or otherwise quantified in terms of their respective viabilities with respect to the length of the segment of interest. For example, anticipated or planned status information (e.g., planned aircraft flight phase, altitude, velocity, or other status or state information, forecasted meteorological conditions, or the like) associated with different locations along the flight path segment being analyzed may be obtained and utilized to analyze the relative viability of each potential diversion destination with respect to those different locations. In this regard, a viability score for a potential diversion destination for each location along the flight path segment for which status information is obtained, and then the resulting viability scores may be averaged to obtain a representative viability score for that diversion destination with respect to the segment. In exemplary embodiments, anticipated status information associated with each of a plurality of alternate destinations and anticipated or forecasted meteorological conditions are also obtained and utilized when determining the viability scores. Accordingly, prior to departure, the potential diversion destinations are scored, graded, or otherwise quantified with respect to a flight path segment in a manner that accounts for the anticipated aircraft operational status along the flight path segment as well as the current or anticipated operational status of each respective destination, current or anticipated status of the route between locations along the flight path segment and the respective destination, and the like. Thus, anticipated operational changes at a given airport, forecasted meteorological conditions, or the like for the anticipated timeframe during which the aircraft will traverse that the flight path segment may be accounted for while also taking into account current conditions.

In one or more embodiments, a graphical user interface (GUI) display is provided that presents or otherwise provides indicia of a recommended diversion destination or the relative viabilities of potential diversion destinations with respect to the flight path segment and enables a pilot or other user to select or otherwise identify which destination he or she would like to associated with that segment of the flight plan prior to departure or otherwise in advance of reaching that segment. In this regard, the GUI display may enable the pilot to sequentially step through the individual segments of the flight plan to define desired diversion destinations along the entire route of the flight plan.

As described in greater detail below in the context of FIGS. 4-6, in one or more embodiments, after departure, the viability scoring and ranking of the potential diversion destinations may be dynamically updated to reflect changing conditions and provide corresponding indications to the pilot. For example, when the aircraft is traveling along a particular flight path segment and the current conditions indicate a particular diversion destination currently has a higher viability with respect to the remainder of the flight path segment yet to be flown than a preselected diversion destination for that flight path segment, one or more graphical indicia or other visual cues may be provided to indicate to the pilot that another diversion destination may be preferable in the event of a need to divert from the flight plan. Thus, when a preselected diversion destination becomes suboptimal or less viable than another potential alternative,

the pilot may be apprised of such changes in real-time while en route, thereby improving the pilot's situational awareness in the event a diversion is necessary. Depending on the embodiment, the preselected diversion destination may be automatically selected (e.g., by a flight management system or similar onboard system) or manually selected, and could be previously selected prior to flying the flight plan, after initiating aircraft operation along the flight plan but prior to flying the current flight path segment, or in some embodiments, potentially after initiating aircraft operation along the current flight path segment but prior to the aircraft reaching its current location.

In one or more embodiments, potential diversion destinations are scored, graded, or otherwise quantified in terms of their respective viabilities with respect to a flight path segment in real-time based at least in part on the current vehicle status as well as the current status of each respective destination, which may also include or otherwise account for the current status of the route to/from the respective destination. Thus, when either the current status of the vehicle (e.g., fuel remaining, aircraft weight, etc.) or the current status of a particular destination or the route thereto (e.g., adverse weather conditions, closed or limited runways, etc.) has potential to complicate use of that destination, the viability of that particular destination may be characterized as having a lower viability than it may otherwise have been absent such complicating factors. In exemplary embodiments, for each potential destination, parameters characterizing the current vehicle status, the current destination status and the current route status for the route between the vehicle and the destination are classified, categorized, or otherwise assigned to a respective parameter group. For each parameter group, a quantitative viability score and a discrete qualitative viability state are calculated or otherwise determined based on the values of the parameters assigned to that parameter group. Thus, each potential destination has a plurality of parameter group viability scores and a plurality of parameter group viability states associated therewith which are indicative of the current viability of that destination.

Each destination is then classified, categorized, or otherwise assigned to a particular aggregate viability group based on its associated parameter group viability states. In this regard, each aggregate viability group is a unique subset of the potential destinations having substantially the same viability across the parameter groups. Within each viability group, the destinations are then ranked, sorted, or otherwise ordered relative to other destinations in that group based on their associated parameter group viability scores. A listing of the potential destinations can then be displayed or otherwise presented, with the destinations within the listing being ranked, sorted, or otherwise ordered primarily by their viability groupings, and then ranked, sorted, or otherwise ordered secondarily within the viability groupings in a manner that reflects the parameter group viability scores. In this regard, destinations in the higher viability groups are displayed preferentially (or with precedence) over destinations in lower viability groups, and within those groups, destinations having higher quantitative viability are displayed preferentially (or with precedence) over destinations in that group. Thus, a vehicle operator can quickly discern which destinations are more or less viable relative to other destinations.

Additionally, graphical indicia representative of the parameter group viability states associated with each potential destination may also be displayed in association with the destination. Thus, a vehicle operator or other user can also

quickly ascertain each potential destination's qualitative viability across a number of different categories, while concurrently gauging that destination's qualitative viability relative to other potential destinations. The graphical indicia representative of the parameter group viability states associated with each potential destination may also be utilized to graphically represent that particular destination on a navigational map, for example, by displaying graphical indicia representative of the parameter group viability states for a destination on the navigational map at the location corresponding to the geographic location of that destination. Thus, a vehicle operator or other user can concurrently achieve situational awareness of the viability characteristics of particular destination displayed on the navigational map while also maintaining awareness of the location of that destination relative to the vehicle.

For example, in one or more embodiments, as described in greater detail below in the context of FIGS. 7-8, the current (or most recent) or anticipated values for base parameters representative of (or indicative of) a current or anticipated status of the aircraft at one or more locations along the flight path segment (e.g., fuel remaining, aircraft weight, altitude, airspeed, heading, mechanical configuration, and the like) may be obtained using systems onboard the aircraft, while current (or most recent) or anticipated values for base parameters representative of (or indicative of) the current status of potential diversion airports may be obtained from external systems. For each potential diversion airport, parameter group viability states and parameter group viability scores are determined for each of a plurality of parameter groups using the base parameter values for the aircraft status and the base parameter values for the airport status, along with any base parameter values characterizing the current or anticipated status of the route to/from the airport and/or complex parameter values calculated for the airport using the base parameters. The potential diversion airports are then classified into different airport viability groupings, and then the airports are ranked within their associated viability grouping based on their associated viability scores for the parameter groups. The highest ranked airport within the grouping having the highest viability is identified as the recommended diversion airport with respect to the flight path segment being analyzed, and a corresponding notification is provided to the pilot or other user.

Referring now to FIG. 1, an exemplary embodiment of a system **100** which may be located onboard a vehicle, such as an aircraft **102**, includes, without limitation, a display device **104**, a user input device **106**, a processing system **108**, a display system **110**, a communications system **112**, a navigation system **114**, a flight management system (FMS) **116**, one or more avionics systems **118**, one or more detection systems **120**, and one or more data storage elements **122**, **124** cooperatively configured to support operation of the system **100**, as described in greater detail below.

In exemplary embodiments, the display device **104** is realized as an electronic display capable of graphically displaying flight information or other data associated with operation of the aircraft **102** under control of the display system **110** and/or processing system **108**. In this regard, the display device **104** is coupled to the display system **110** and the processing system **108**, wherein the processing system **108** and the display system **110** are cooperatively configured to display, render, or otherwise convey one or more graphical representations or images associated with operation of the aircraft **102** on the display device **104**. For example, as described in greater detail below, a navigational map that includes a graphical representation of the aircraft **102** and

one or more of the terrain, meteorological conditions, airspace, air traffic, navigational reference points, and a route associated with a flight plan of the aircraft **102** may be displayed, rendered, or otherwise presented on the display device **104**.

The user input device **106** is coupled to the processing system **108**, and the user input device **106** and the processing system **108** are cooperatively configured to allow a user (e.g., a pilot, co-pilot, or crew member) to interact with the display device **104** and/or other elements of the aircraft system **100**, as described in greater detail below. Depending on the embodiment, the user input device **106** may be realized as a keypad, touchpad, keyboard, mouse, touch panel (or touchscreen), joystick, knob, line select key or another suitable device adapted to receive input from a user. In some embodiments, the user input device **106** is realized as an audio input device, such as a microphone, audio transducer, audio sensor, or the like, that is adapted to allow a user to provide audio input to the aircraft system **100** in a “hands free” manner without requiring the user to move his or her hands, eyes and/or head to interact with the aircraft system **100**.

The processing system **108** generally represents the hardware, circuitry, processing logic, and/or other components configured to facilitate communications and/or interaction between the elements of the aircraft system **100** and perform additional processes, tasks and/or functions to support operation of the aircraft system **100**, as described in greater detail below. Depending on the embodiment, the processing system **108** may be implemented or realized with a general purpose processor, a controller, a microprocessor, a microcontroller, a content addressable memory, a digital signal processor, an application specific integrated circuit, a field programmable gate array, any suitable programmable logic device, discrete gate or transistor logic, processing core, discrete hardware components, or any combination thereof, designed to perform the functions described herein. In practice, the processing system **108** includes processing logic that may be configured to carry out the functions, techniques, and processing tasks associated with the operation of the aircraft system **100** described in greater detail below. Furthermore, the steps of a method or algorithm described in connection with the embodiments disclosed herein may be embodied directly in hardware, in firmware, in a software module executed by the processing system **108**, or in any practical combination thereof. In accordance with one or more embodiments, the processing system **108** includes or otherwise accesses a data storage element **124**, such as a memory (e.g., RAM memory, ROM memory, flash memory, registers, a hard disk, or the like) or another suitable non-transitory short or long term storage media capable of storing computer-executable programming instructions or other data for execution that, when read and executed by the processing system **108**, cause the processing system **108** to execute and perform one or more of the processes, tasks, operations, and/or functions described herein.

The display system **110** generally represents the hardware, firmware, processing logic and/or other components configured to control the display and/or rendering of one or more displays pertaining to operation of the aircraft **102** and/or systems **112**, **114**, **116**, **118**, **120** on the display device **104** (e.g., synthetic vision displays, navigational maps, and the like). In this regard, the display system **110** may access or include one or more databases **122** suitably configured to support operations of the display system **110**, such as, for example, a terrain database, an obstacle database, a naviga-

tional database, a geopolitical database, a terminal airspace database, a special use airspace database, or other information for rendering and/or displaying navigational maps and/or other content on the display device **104**. In this regard, in addition to including a graphical representation of terrain, a navigational map displayed on the display device **104** may include graphical representations of navigational reference points (e.g., waypoints, navigational aids, distance measuring equipment (DMEs), very high frequency omnidirectional radio ranges (VORs), and the like), designated special use airspaces, obstacles, and the like overlying the terrain on the map.

As described in greater detail below, in an exemplary embodiment, the processing system **108** includes or otherwise accesses a data storage element **124** (or database), which maintains information regarding airports and/or other potential landing locations (or destinations) for the aircraft **102**. In this regard, the data storage element **124** maintains an association between a respective airport, its geographic location, runways (and their respective orientations and/or directions), instrument procedures (e.g., approaches, arrival routes, and the like), airspace restrictions, and/or other information or attributes associated with the respective airport (e.g., widths and/or weight limits of taxi paths, the type of surface of the runways or taxi path, and the like). Additionally, in accordance with one or more embodiments, the data storage element **122** also maintains airport status information for the runways and/or taxi paths at the airport indicating whether or not a particular runway and/or taxi path is currently operational along with directional information for the taxi paths (or portions thereof). The data storage element **122** may also be utilized to store or maintain other information pertaining to the airline or aircraft operator (e.g., contractual agreements or other contractual availability information for particular airports, maintenance capabilities or service availability information for particular airports, and the like) along with information pertaining to the pilot and/or co-pilot of the aircraft (e.g., experience level, licensure or other qualifications, work schedule or other workload metrics, such as stress or fatigue estimates, and the like).

Still referring to FIG. 1, in an exemplary embodiment, the processing system **108** is coupled to the navigation system **114**, which is configured to provide real-time navigational data and/or information regarding operation of the aircraft **102**. The navigation system **114** may be realized as a global positioning system (GPS), inertial reference system (IRS), or a radio-based navigation system (e.g., VHF omnidirectional radio range (VOR) or long range aid to navigation (LORAN)), and may include one or more navigational radios or other sensors suitably configured to support operation of the navigation system **114**, as will be appreciated in the art. The navigation system **114** is capable of obtaining and/or determining the instantaneous position of the aircraft **102**, that is, the current (or instantaneous) location of the aircraft **102** (e.g., the current latitude and longitude) and the current (or instantaneous) altitude (or above ground level) for the aircraft **102**. The navigation system **114** is also capable of obtaining or otherwise determining the heading of the aircraft **102** (i.e., the direction the aircraft is traveling in relative to some reference).

In an exemplary embodiment, the processing system **108** is also coupled to the FMS **116**, which is coupled to the navigation system **114**, the communications system **112**, and one or more additional avionics systems **118** to support navigation, flight planning, and other aircraft control functions in a conventional manner, as well as to provide

real-time data and/or information regarding the operational status of the aircraft **102** to the processing system **108**. It should be noted that although FIG. **1** depicts a single avionics system **118**, in practice, the aircraft system **100** and/or aircraft **102** will likely include numerous avionics systems for obtaining and/or providing real-time flight-related information that may be displayed on the display device **104** or otherwise provided to a user (e.g., a pilot, a co-pilot, or crew member). For example, practical embodiments of the aircraft system **100** and/or aircraft **102** will likely include one or more of the following avionics systems suitably configured to support operation of the aircraft **102**: a weather system, an air traffic management system, a radar system, a traffic avoidance system, an autopilot system, an autothrust system, a flight control system, hydraulics systems, pneumatics systems, environmental systems, electrical systems, engine systems, trim systems, lighting systems, crew alerting systems, electronic checklist systems, an electronic flight bag and/or another suitable avionics system.

In the illustrated embodiment, the onboard detection system(s) **120** generally represents the component(s) of the aircraft **102** that are coupled to the processing system **108** and/or the display system **110** to generate or otherwise provide information indicative of various objects or regions of interest within the vicinity of the aircraft **102** that are sensed, detected, or otherwise identified by a respective onboard detection system **120**. For example, an onboard detection system **120** may be realized as a weather radar system or other weather sensing system that measures, senses, or otherwise detects meteorological conditions in the vicinity of the aircraft **102** and provides corresponding radar data (e.g., radar imaging data, range setting data, angle setting data, and/or the like) to one or more of the other onboard systems **108**, **110**, **114**, **116**, **118** for further processing and/or handling. For example, the processing system **108** and/or the display system **110** may generate or otherwise provide graphical representations of the meteorological conditions identified by the onboard detection system **120** on the display device **104** (e.g., on or overlying a lateral navigational map display). In another embodiment, an onboard detection system **120** may be realized as a collision avoidance system that measures, senses, or otherwise detects air traffic, obstacles, terrain and/or the like in the vicinity of the aircraft **102** and provides corresponding detection data to one or more of the other onboard systems **108**, **110**, **114**, **116**, **118**.

In the illustrated embodiment, the processing system **108** is also coupled to the communications system **112**, which is configured to support communications to and/or from the aircraft **102** via a communications network. For example, the communications system **112** may also include a data link system or another suitable radio communication system that supports communications between the aircraft **102** and one or more external monitoring systems, air traffic control, and/or another command center or ground location. In this regard, the communications system **112** may allow the aircraft **102** to receive information that would otherwise be unavailable to the pilot and/or co-pilot using the onboard systems **114**, **116**, **118**, **120**. For example, the communications system **112** may receive meteorological information from an external weather monitoring system, such as a Doppler radar monitoring system, a convective forecast system (e.g., a collaborative convective forecast product (CCFP) or national convective weather forecast (NCWF) system), an infrared satellite system, or the like, that is capable of providing information pertaining to the type, location and/or severity of precipitation, icing, turbulence,

convection, cloud cover, wind shear, wind speed, lightning, freezing levels, cyclonic activity, thunderstorms, or the like along with other weather advisories, warnings, and/or watches. The meteorological information provided by an external weather monitoring system may also include forecast meteorological data that is generated based on historical trends and/or other weather observations, and may include forecasted meteorological data for geographical areas that are beyond the range of any weather detection systems **120** onboard the aircraft **102**. In other embodiments, the processing system **108** may store or otherwise maintain historic meteorological data previously received from an external weather monitoring system, with the processing system **108** calculating or otherwise determining forecast meteorological for geographic areas of interest to the aircraft **102** based on the stored meteorological data and the current (or most recently received) meteorological data from the external weather monitoring system. In this regard, the meteorological information from the external weather monitoring system may be operationally used to obtain a “big picture” strategic view of the current weather phenomena and trends in its changes in intensity and/or movement with respect to prospective operation of the aircraft **102**.

It should be understood that FIG. **1** is a simplified representation of the aircraft system **100** for purposes of explanation and ease of description, and FIG. **1** is not intended to limit the application or scope of the subject matter described herein in any way. It should be appreciated that although FIG. **1** shows the display device **104**, the user input device **106**, and the processing system **108** as being located onboard the aircraft **102** (e.g., in the cockpit), in practice, one or more of the display device **104**, the user input device **106**, and/or the processing system **108** may be located outside the aircraft **102** (e.g., on the ground as part of an air traffic control center or another command center) and communicatively coupled to the remaining elements of the aircraft system **100** (e.g., via a data link and/or communications system **112**). In this regard, in some embodiments, the display device **104**, the user input device **106**, and/or the processing system **108** may be implemented as an electronic flight bag that is separate from the aircraft **102** but capable of being communicatively coupled to the other elements of the aircraft system **100** when onboard the aircraft **102**. Similarly, in some embodiments, the data storage element **124** may be located outside the aircraft **102** and communicatively coupled to the processing system **108** via a data link and/or communications system **112**. Furthermore, practical embodiments of the aircraft system **100** and/or aircraft **102** will include numerous other devices and components for providing additional functions and features, as will be appreciated in the art. In this regard, it will be appreciated that although FIG. **1** shows a single display device **104**, in practice, additional display devices may be present onboard the aircraft **102**. Additionally, it should be noted that in other embodiments, features and/or functionality of processing system **108** described herein can be implemented by or otherwise integrated with the features and/or functionality provided by the display system **110** or the FMS **116**, or vice versa. In other words, some embodiments may integrate the processing system **108** with the display system **110** or the FMS **116**; that is, the processing system **108** may be a component of the display system **110** and/or the FMS **116**.

Referring now to FIG. **2**, in an exemplary embodiment, the system **100** is configured to support a route diversion selection process **200** and perform additional tasks, functions, and operations described below. The various tasks performed in connection with the illustrated process **200**

may be implemented using hardware, firmware, software executed by processing circuitry, or any combination thereof. For illustrative purposes, the following description may refer to elements mentioned above in connection with FIG. 1. In practice, portions of the route diversion selection process 200 may be performed by different elements of the system 100, such as, the processing system 108, the display system 110, the communications system 112, the navigation system 114, the FMS 116, the onboard avionics systems 118 and/or the onboard detection systems 120. It should be appreciated that the route diversion selection process 200 may include any number of additional or alternative tasks, the tasks need not be performed in the illustrated order and/or the tasks may be performed concurrently, and/or the route diversion selection process 200 may be incorporated into a more comprehensive procedure or process having additional functionality not described in detail herein. Moreover, one or more of the tasks shown and described in the context of FIG. 2 could be omitted from a practical embodiment of the route diversion selection process 200 as long as the intended overall functionality remains intact.

In one or more embodiments, the route diversion selection process 200 is performed with respect to a particular flight plan prior to departure of the aircraft along that flight plan. For example, the route diversion selection process 200 may be performed while the aircraft is on the ground to enable a pilot to review the route defined by the flight plan and designate his or her desired diversion (or alternate) destinations along the route for use in the event of an emergency or other situation necessitating a diversion.

In an exemplary embodiment, the route diversion selection process 200 begins by identifying or otherwise determining a flight path segment for which potential diversion destinations should be analyzed (task 202). In this regard, the route defined by the flight plan may be subdivided into a series of consecutive segments that make up the route. In exemplary embodiments, when the aircraft has not yet begun executing the flight plan, the route diversion selection process 200 begins by analyzing the initial flight path segment closest to the departure location and proceeds sequentially through the flight path segments from the departure location to the destination location until a diversion airport has been selected for each flight path segment. That said, in other embodiments, the route diversion selection process 200 may begin at other locations within the route of the flight plan. For example, when performed during operation of the aircraft in accordance with the flight plan, the route diversion selection process 200 may begin by identifying and analyzing a flight path segment that the aircraft is currently traversing.

In practice, the flight path segments may be defined in any number of ways. For example, in one or more embodiments, the pilot, co-pilot, or the like may manipulate a GUI display to define the number segments for which the flight plan route should be divided into along with the corresponding length (e.g., geographic distance and/or flight time duration) associated with the respective segments. In other embodiments, the selection process 200 may automatically divide the route of the flight plan into a number of equal segments having the same length or duration, which may be manually defined by the pilot or other user. In one or more embodiments, the flight path segments are defined independent of the navigational reference points that define the route of the flight plan. For example, a respective flight path segment may begin at a first geographic location along the flight plan route between two successive navigational reference points defining the flight plan route and end at a second geographic

location along the flight plan route between another set of navigational reference points. That said, in other embodiments, the flight path segments may be defined by the navigational reference points of the flight plan. For example, each flight path segment may begin at one navigational reference point and end at the next successive reference point.

After identifying the flight path segment of interest, the selection process 200 continues by identifying or otherwise determining a subset of potential airports to be analyzed with respect to that flight path segment based on the flight path segment (task 204). In this regard, the selection process 200 may apply one or more filtering criteria to all of the potential diversion destinations within a geographic area encompassing the entire route of the flight plan to reduce the number of diversion destinations for analysis as those most relevant to the flight path segment of interest. For example, the selection process 200 may filter or otherwise exclude from further analysis any airports that are not within a threshold geographic distance of the flight path segment, within a threshold flight time of the flight path segment, and/or require more than a threshold amount of fuel to reach from one or more locations along or throughout the entire duration of the flight path segment. In this regard, the selection process 200 may individually analyze discrete locations along the flight path segment to ensure that each airport retained in the subset is likely to be within the threshold distance or flight time of the aircraft during operation along that flight path segment and be reachable by the aircraft given the current or anticipated amount of fuel onboard.

For example, the selection process 200 may confirm that at least the starting location of the flight path segment, the ending location of the flight path segment, and one or more intermediate locations along the flight path segment (e.g., the midpoint between the starting and ending locations) are each within the threshold distance or flight time of a potential diversion airport, otherwise that particular potential diversion airport is excluded from further analysis with respect to the flight path segment. In one or more embodiments, the threshold distance or flight time is calculated or otherwise determined based on the anticipated amount of fuel remaining onboard the aircraft at one or more locations along the flight path segment being analyzed (e.g., the predicted amount of fuel remaining at the end of the flight path segment). In other embodiments, the pilot or other user may define (e.g., via one or more GUI elements) the filtering criteria to be utilized to limit the diversion destinations considered. In one embodiment, the currently displayed geographic area of a navigational map displayed on the display device 104 is used as a filtering criterion, such that only airports or destinations within the displayed geographic area are considered by excluding airports that are not located within the displayed geographic area.

Still referring to FIG. 2, after identifying the subset of airports to be analyzed, the selection process 200 continues by ranking, prioritizing, or otherwise ordering the airports within the subset of airports relevant to the flight path segment in terms of their relative viabilities with respect to the aircraft, and generating or otherwise providing graphical indicia of the recommended airport(s) with respect to the flight path segment (tasks 206, 208). In exemplary embodiments, as described in greater detail below in the context of FIGS. 7-8, the route diversion selection process 200 ranks the airports using real-time (or near real-time), forecasted, or anticipated status information and the airports' respective viabilities for various parameter groupings. For example, for

each airport of the filtered subset, route diversion selection process **200** receives or otherwise obtains current and/or anticipated status information for the respective airport, such as, for example, current and/or forecasted meteorological conditions, current and/or anticipated operating status of the runways at the airport, current and/or anticipated airspace restrictions at the airport, and the like. The route diversion selection process **200** also obtains status information associated with the flight path segment for the aircraft **102** using the flight plan maintained by the FMS **116**, such as, for example, the anticipated altitude (or above ground level) for the aircraft **102** at one or more locations along the flight path segment according to the flight plan, the anticipated locations of the aircraft **102** along the flight path segment, the anticipated aircraft headings at one or more locations along the flight path segment according to the flight plan, the anticipated aircraft velocity along the flight path segment according to the flight plan, the anticipated amount of fuel remaining onboard the aircraft, and the like. In this regard, in some embodiments, the status information associated with the flight path segment for the aircraft **102** may be calculated as an average of the values across the entire length of the flight path segment (e.g., by averaging the altitude at the start of the segment and the altitude at the end of the segment). When the route diversion selection process **200** is performed during execution of the flight path segment being analyzed, the selection process **200** obtains the current real-time status information for the aircraft **102**, such as the current or instantaneous altitude, location, heading, velocity, and the like.

As described in greater detail below in the context of FIGS. 7-8, in one or more embodiments, for each airport, a respective parameter group viability score is determined for each of a plurality of parameter groups using the status information for that airport and the aircraft. Additionally, a respective parameter group viability state is determined for each of the plurality of parameter groups for the respective airport. Based on the respective parameter group viability states, the airports are then classified into different aggregate viability groups. In this regard, the airports classified into a respective one of the aggregate viability groups represent a subset of the airports being analyzed having a substantially similar viability status. Each airport is then ranked within its respective viability group based on its respective parameter group viability scores relative to those of other airports within its respective aggregate viability group. Thus, better or more preferred airports may be discerned from other airports with the same general viability. Thereafter, the identified airports within the filtered subset are then ranked or otherwise ordered primarily based on the respective aggregate viability groupings and then secondarily based on each respective airports relative ranking within its respective aggregate viability group, resulting in a prioritized list of the potential diversion destinations for the flight path segment.

In exemplary embodiments, the route diversion selection process **200** highlights, indicates, or otherwise identifies the recommended airport(s) for the flight path segment on the display device **104**. For example, a graphical representation of the highest ranked airport may be rendered with a visually distinguishable characteristic to provide a visual cue highlighting that airport relative to the graphical representations of other airports within the filtered subset that was analyzed for the flight path segment. In some embodiments, the selection process **200** generates or otherwise provides an ordered list of the ranked airports, with the recommended

airport(s) being preferentially displayed (e.g., at the top of the list, at the left within the list, visually distinguished within the list, etc.).

In one or more embodiments, the route diversion selection process **200** also displays or otherwise presents graphical indicia of the respective parameter group viability states for each airport presented. In this regard, while highlighting the recommended airport(s) or providing an ordered list on the display device **104** allows a pilot or other user to immediately distinguish which airports are most viable from those that are less viable, the parameter group viability state indicia allow the pilot to quickly discern the general viability characteristics associated with each individual airport presented. In exemplary embodiments, each parameter group viability state is rendered with a visually distinguishable characteristic that is different from those of the other parameter group viability states. The visually distinguishing characteristic may include one or more of a visually distinguishable color, hue, tint, brightness, graphically depicted texture or pattern, contrast, transparency, opacity, shading, animation, line type, and/or other graphical effect that visually distinguish a parameter group viability state. In one exemplary embodiment, the route diversion selection process **200** supports three different parameter group viability states, with the visually distinguishing characteristics being realized as three distinct colors. For example, the highest or best parameter group viability state may be indicated using a green color, with the lowest or worst parameter group viability state being indicated using a red color, and the intermediate parameter group viability state being indicated using a yellow color.

In one or more embodiments, the symbologies or representations of the presented airports are selectable, and the route diversion selection process **200** displays or otherwise presents detail information for the respective parameter groups for an individual airport in response to selection of that airport. In this regard, when the user input device **106** is manipulated to select a particular airport on the display device **104**, the processing system **108** may generate or otherwise provide a pop-up or other graphical user interface (GUI) display on the display device **104** that includes more specific or detailed information regarding the parameter group viability states for that airport, which may be ordered by perceived relevance. The detail information may include the factors or criteria that primarily governed assigning or classifying a particular viability state to a particular parameter group. For example, in the case of a binary parameter resulting in the lowest viability designation, the detail information may include further information regarding that parameter. Additionally, the detail information may also be displayed or otherwise rendered using the same visually distinguishable characteristic as its associated parameter group viability state. For example, detail information regarding a binary parameter resulting in the lowest viability designation for a particular parameter group may be rendered in red. Conversely, detail information regarding a parameter that contributes to or otherwise results in the highest viability designation for a particular parameter group may be rendered in green.

Still referring to FIG. 2, the selection process **200** continues by designating or otherwise associating an alternate airport with the flight path segment (task **210**). In one or more embodiments, the selection process **200** automatically establishes an initial association between the highest ranked (or recommended) airport and the flight path segment. In other embodiments, the selection process **200** establishes the association in response to receiving an input from the pilot

or other user indicative of a desired airport from among the subset of airports capable of being associated with the flight path segment (e.g., those remaining in the filtered subset at task 204). In this regard, in some embodiments, the highest ranked airport from the filtered subset may be assigned to the flight path segment by default, but that assignment is capable of being overridden by the pilot. For example, as described in greater detail below in the context of FIG. 3, one or more graphical user interface (GUI) elements may be provided that allow the pilot to select and associate an airport that is not the highest ranked airport with respect to a given flight path segment. In exemplary embodiments, the association between the flight path segment and diversion airport and the corresponding definitions of the flight path segment are maintained in conjunction with the flight plan (e.g., in a data storage element associated with or accessible to the FMS 116) to facilitate providing graphical representations of the flight path segment and the corresponding diversion destination during execution of the flight plan, as described in greater detail below.

In exemplary embodiments, once a diversion airport is associated with a flight path segment, the selection process 200 is repeated for the next flight path segment following that initial flight path segment until a diversion airport has been associated or assigned to each flight path segment of a flight plan. In this regard, the selection process 200 may generate or otherwise provide a diversion airport selection GUI display sequence (or wizard) that steps through the flight path segments of a flight plan to allow the pilot or other user to manually review the highest ranked airport associated with each flight path segment and confirm or override the airport prioritization with respect to that flight path segment. In other embodiments, the selection process 200 may be performed essentially as a background process to automatically assign flight path segments with the highest ranked airport for each flight path segment. For example, in one embodiment, the FMS 116 may automatically divide the flight plan into equally sized flight path segments, and then automatically associates each flight path segment with the highest ranked airport from within the subset of airports satisfying the applicable filtering criteria (e.g., maximum distance, maximum flight time, maximum fuel required, and/or the like) with respect to the respective flight path segment. In such embodiments, the pilot or other user may then subsequently review the flight path segments and associated default diversion airports and modify the number and/or length of the flight path segments and/or modify the diversion airport associated with a respective flight path segment.

FIG. 3 depicts an exemplary navigational map display 300 that may be displayed, rendered, or otherwise presented by the display system 110 and/or the processing system 108 on the display device 104 in conjunction with the route diversion selection process 200 of FIG. 2. The illustrated navigational map 300 includes a graphical representation 302 of the flight plan overlaid or rendered on top of a background 304. In this regard, FIG. 3 depicts a flight plan 302 including five navigational reference points 306 defining a route from an initial departure location 305 (e.g., airport LGPB) to a destination (or arrival) location 307 (e.g., airport LRPB). In the illustrated embodiment, the map 300 is centered on the flight plan 302 such that the center location of the navigational map 300 corresponds to the midpoint of the flight plan 302. That said, in alternative embodiments, the center location of the navigational map 300 may correspond to a geographic location that is independent of the flight plan 302, for example, when a user

manipulates a user input device 106 to scroll the displayed area of the navigational map or select a portion of the displayed area that does not include the flight plan 302.

The background 304 comprises a graphical representation of the terrain, topology, navigational reference points, airspace designations and/or restrictions, or other suitable items or points of interest corresponding to the currently displayed area of the navigational map 300, which may be maintained in a terrain database, a navigational database, a geopolitical database, or another suitable database. For example, the display system 110 may render a graphical representation of nearby navigational aids (e.g., VORs, VORTACs, DMEs, and the like) and airports within the currently displayed geographic area of the navigational map 300 overlying the background 304. Some embodiments of navigational map 300 may also include graphical representations of airspace designations and/or airspace restrictions, cities, towns, roads, railroads, and other geo-political information. In addition, depending on the embodiment, other real-time flight related information that is within the geographic area corresponding to the currently displayed area of the navigational map 300 or within a particular proximity of the aircraft may be rendered on the map 300, such as, for example, weather conditions, radar data, neighboring air traffic, and the like, as will be appreciated in the art. Although FIG. 3 depicts a top view of the navigational map 300 (alternatively referred to as a lateral map or lateral view), in practice, alternative embodiments may utilize various perspective views, such as side views, three-dimensional views (e.g., a three-dimensional synthetic vision display), angular or skewed views, and the like.

The illustrated map 300 corresponds to an instance of the selection process 200 being performed prior to the aircraft 102 departing the departure location (e.g., airport LGPB). That said, in other embodiments, the navigational map 300 is associated with the movement of the aircraft 102, includes a graphical representation of the aircraft 102 overlying the background 304, and the aircraft symbology and/or background 304 refreshes or otherwise updates as the aircraft 102 travels, such that the graphical representation of the aircraft 102 is positioned over the terrain background 304 in a manner that accurately reflects the current (e.g., instantaneous or substantially real-time) real-world positioning of the aircraft 102 relative to the earth. For example, in some embodiments, the aircraft symbology is shown as traveling across the navigational map 300 (e.g., by updating the location of the aircraft symbology with respect to the background 304), while in other embodiments, the aircraft symbology may be located at a fixed position on the navigational map 300 (e.g., by updating the background 304 with respect to the aircraft graphic such that the map 300 is maintained centered on and/or aligned with the aircraft graphic). Additionally, depending on the embodiment, the navigational map 300 may be oriented in a cardinal direction (e.g., oriented north-up so that moving upward on the map 300 corresponds to traveling northward), or alternatively, the orientation of the navigational map 300 may be track-up or heading-up (i.e., aligned such that the aircraft symbology is always traveling in an upward direction and the background 304 adjusted accordingly).

In the illustrated embodiment, the flight plan 302 is divided into three flight path segments 310, 312, 314 defined independently of the navigational reference points 306. For example, the length of the portion of the route defined by the flight plan 302 that is not within a threshold distance of the departure location 305, (e.g., the portion where an alternate or diversion airport does not need to be defined) may be

automatically divided into a predefined number of flight path segments (e.g., four segments) having substantially equal length. Alternatively, the flight plan **302** may be automatically divided into flight path segments having a predefined distance. That said, in other embodiments, the pilot or other user may manipulate one or more GUI elements to add or remove flight path segments as well as increase and/or decrease the length of one or more flight path segments (e.g., by dragging an end of a flight path segment along the flight plan **302** in the desired direction). In yet other alternative embodiments, the flight plan **302** may be divided into flight path segments defined by the consecutive waypoints (e.g., six segments between departure and destination locations **305**, **307**).

Referring to FIGS. 2-3, in response to identifying a flight path segment of interest, such as initial flight path segment **310** (e.g., task **202**), the display system **110** and/or the processing system **108** graphically indicates or otherwise highlights the flight path segment **310** being analyzed on the display device **104**, for example, by rendering the flight path segment **310** with a visually distinguishable fill pattern or other visually distinguishable characteristic. As described above, the selection process **200** identifies a subset of airports **320**, **322**, **324** satisfying applicable filtering criteria with respect to the flight path segment **310** and displays, renders, or otherwise graphically indicates the potential diversion airports **320**, **322**, **324** for the flight path segment **310** on the map **300**. In exemplary embodiments, the airport symbology presented on the navigational map **300** includes graphical indicia representative of the parameter group viability states for the displayed airports **320**, **322**, **324**. For example, a consolidated graphical indicia, such as a pie chart where the different sectors (or slices) are representative of the different parameter groups, may also be utilized for the airport symbology **320**, **322**, **324**. In this regard, FIG. 3 depicts an embodiment where four different parameter groups are being utilized to rank the airports, however, it should be appreciated that the subject matter is not intended to be limited to any particular number of parameter groups. It should be noted that the subject matter described herein is not limited to pie charts, and other similar graphics may be utilized to represent the parameter group states in a consolidated manner. In this regard, a concise representation allows for faster orientation and understanding of the relative airport viability and components thereof.

In the embodiment of FIG. 3, each of the sectors of the pie chart indicia for the airports **322**, **324** having the highest viability are rendered using the visually distinguishable characteristic associated with the highest parameter group viability state (e.g., green). In this manner, the pilot of the aircraft **102** can quickly identify those airports **322**, **324** as having the highest viability state across the various parameter groups with respect to the current flight path segment **310** being analyzed. The display system **110** and/or the processing system **108** also displays, renders, or otherwise provides an additional visually distinguishable graphical indication **325** associated with the LKBP airport symbology **324** to indicate that airport LKBP is recommended or highest ranked with respect to flight path segment **310**. Thus, a pilot can quickly identify that airport LKBP **324** was scored higher than the other airports **320**, **322** with respect to the current flight path segment **310**. In some embodiments, an ordered list of the potential airports for the flight path segment of interest may be displayed on the map **300**. For example, a list including a graphical representation of airport LKBP **324** preferentially displayed over the remaining airports **320**, **322** may be displayed on the navigational map

304, with a graphical representation of airport LKPL **322** being preferentially displayed over airport LKDD **320**, thereby allowing the pilot to quickly ascertain the relative viability of all of the depicted airports **320**, **322**, **324**.

One or more of the sectors of the pie chart indicia for the airport symbology **320** associated with the airport having an intermediate or low viability are rendered using the visually distinguishable characteristic associated with the corresponding intermediate or lower parameter group viability state (e.g., yellow, red, or the like), while remaining sectors of the pie chart indicia **410** for each respective airport are rendered using the visually distinguishable characteristic associated with the highest parameter group viability state (e.g., green). Thus, the pilot of the aircraft **102** can quickly identify the number of parameter groups for airport LKDD **320** that do not have the highest viability state, as well as identify which parameter group(s) could potentially compromise or complicate landing at airport LKDD **320**.

In one or more embodiments, the airport symbology **320**, **322**, **324** is selectable or otherwise manipulable by a user to designate and thereby assign a particular diversion airport to the flight path segment **310** being analyzed. That said, in other embodiments, a GUI element **330**, such as a window or drop box, or another GUI display may be presented on the display device **104** (e.g., on, overlying, or adjacent to the map **300**) that allows the user to manually input the desired diversion airport by selecting, activating, manipulating, or otherwise interacting with the respective GUI element **330** (e.g., textually, via speech recognition, dragging and dropping the airport symbology for the desired airport, or the like). For example, FIG. 3 depicts an example where the pilot drags and drops the LKPL symbol **322** into the alternate airport selection box **330** to thereby override and designate LKPL as the alternate airport for the flight path segment **310** instead of the more highly ranked LKBP airport. In response to identifying selection of a desired diversion airport for the flight path segment **310** being analyzed, the processing system **108** updates the flight plan data maintained in the data storage element **124** to include information identifying the desired diversion airport in association with the information defining the flight path segment **310** for which the selected diversion airport is active or otherwise applicable.

After selection of an airport for association with the flight path segment **310**, the display system **110** and/or the processing system **108** may update the navigational map **300** by removing the displayed airports **320**, **322**, **324**, deemphasizing the previously analyzed flight path segment **310**, and sequentially proceeding to the next flight segment **312**. In this regard, the selection process **200** repeats by graphically indicating or highlighting the next flight path segment **312** to be analyzed on the display device **104** along with providing graphical representations of the potential diversion airports associated with the next flight path segment **312**, graphical indicia of the recommended or highest ranked diversion airport for the next flight path segment **312**, graphical indicia of the relative viabilities of the potential diversion airports presented, and so on until diversion airports have been designated or otherwise associated with flight path segments **312**, **314** that make up the remainder of the flight plan **302**.

FIG. 4 depicts an exemplary embodiment of an en route diversion display diversion display process **400** suitable for implementation by the system **100** in conjunction with the route diversion selection process **200** of FIG. 2. The various tasks performed in connection with the illustrated diversion display process **400** may be implemented using hardware, firmware, software executed by processing circuitry, or any

combination thereof. For illustrative purposes, the following description may refer to elements mentioned above in connection with FIG. 1. In practice, portions of the en route diversion display diversion display process 400 may be performed by different elements of the system 100, such as, the processing system 108, the display system 110, the communications system 112, the navigation system 114, the FMS 116, the onboard avionics systems 118 and/or the onboard detection systems 120. It should be appreciated that the en route diversion display diversion display process 400 may include any number of additional or alternative tasks, the tasks need not be performed in the illustrated order and/or the tasks may be performed concurrently, and/or the en route diversion display diversion display process 400 may be incorporated into a more comprehensive procedure or process having additional functionality not described in detail herein. Moreover, one or more of the tasks shown and described in the context of FIG. 4 could be omitted from a practical embodiment of the diversion display diversion display process 400 as long as the intended overall functionality remains intact.

In one or more exemplary embodiments, the en route diversion display diversion display process 400 is performed while the aircraft 102 is en route along a flight plan for which the selection process 200 has previously been performed to designate or associate diversion destinations along the route. In such embodiments, the en route diversion display diversion display process 400 dynamically analyzes the viability of the potential diversion airports for the current flight path segment actively being flown by the aircraft 102 based on current real-time status information associated with the aircraft 102 and the diversion airports and notifies the pilot or other user associated with operation of the aircraft 102 when the recommended or highest ranked diversion destination is different from one previously associated with the current flight path segment. That said, in other embodiments, the en route diversion display diversion display process 400 may also be performed without diversion destinations being previously selected along the route, in which case, the en route diversion display diversion display process 400 dynamically indicates a recommended diversion airport to the pilot in real-time.

In an exemplary embodiment, the en route diversion display diversion display process 400 begins by receiving or otherwise obtaining current status information associated with the aircraft (task 402). The current status information pertaining to the aircraft 102 generally represents the instantaneous, real-time or most recent available values for one or more parameters that quantify the current operation of the aircraft 102. In this regard, the current aircraft status information provides one or more base parameters for scoring or otherwise grading the viability of an airport with respect to one or more parameter groups, as described in greater detail below. For example, the processing system 108 may obtain (e.g., from FMS 116, navigation system 114 and/or other avionics systems 118) one or more of the following: the current flight phase for the aircraft 102, the current location of the aircraft 102 (or a particular distance from a navigational reference point or a desired track), the current altitude (or above ground level) of the aircraft 102, the current heading (or bearing) of the aircraft 102, the current amount of fuel remaining onboard the aircraft 102, the current engine status (e.g., whether any engine is disabled, whether afterburners are in operation, the current revolutions per minute, and/or the like), the current aircraft configuration (e.g., the current flap configuration). Additionally, the processing system 108 may obtain, either from the onboard

detection systems 120 or an external system via communications system 112, current meteorological conditions at or near the current location of the aircraft 102 (e.g., the current temperature, wind speed, wind direction, atmospheric pressure, turbulence, and the like), the current air traffic or other obstacles at or near the current location of the aircraft 102, and the like.

The diversion display process 400 continues by identifying or otherwise determining the flight path segment for which potential diversion destinations should be analyzed (task 404). In this regard, using the current location, the current heading, the current velocity or airspeed, and the like, the diversion display process 400 identifies which of the flight path segments associated with the flight plan should be analyzed based on the aircraft's current status along the route. In one or more exemplary embodiments, the diversion display process 400 identifies the flight path segment that most closely corresponds to the current aircraft location and heading as the flight path segment to be analyzed, that is, the flight path segment the aircraft 102 is currently traveling along (i.e., the current flight path segment). For example, the processing system 108 may compare the current geographic location of the aircraft 102 with the information defining the flight path segments that the flight plan is divided into (e.g., task 202), and then identify which flight path segment the current aircraft location matches or otherwise corresponds to. In this regard, the current aircraft heading may also be utilized to resolve any ambiguities at or near the transition between flight path segments.

In some embodiments, when the current aircraft location is within a threshold distance of the ending location for the current flight path segment, the processing system 108 may select or otherwise identify the next flight path segment following the flight path segment the aircraft 102 is currently traveling along for analysis. In other words, based on the current location, heading and/or velocity of the aircraft 102 with respect to the end of the current flight path segment, the diversion display process 400 may intelligently identify that a future flight path segment should be analyzed due to the unlikelihood of a diversion before the aircraft 102 finishes traveling the current flight path segment. That said, for purposes of explanation, the subject matter may be described herein primarily in the context of the current flight path segment the aircraft 102 is currently traveling along.

Once the flight path segment to be analyzed is identified, the diversion display process 400 continues by analyzing potential diversion airports with respect to the remaining portion of that flight path segment yet to be flown by the aircraft based on the current status information associated with the aircraft along with the current status information associated with the potential diversion airports (tasks 406, 408, 410). In a similar manner as described above, in exemplary embodiments, the diversion display process 400 continues by identifying or otherwise determining a subset of potential airports to be analyzed with respect to the current flight path segment based on the current aircraft status information and the remaining flight path segment. In this regard, the diversion display process 400 may similarly apply one or more filtering criteria to reduce the number of diversion destinations for analysis to those most relevant to the remaining portion of the flight path segment yet to be flown ahead of the current aircraft location. For example, starting from the current aircraft location, the diversion display process 400 may individually analyze discrete locations ahead of the aircraft along the current flight path segment to ensure that each airport retained in the subset is

likely to be within the threshold distance or flight time of the aircraft during future operation along the flight path segment. In a similar manner as described above, the selection process 200 may confirm that at least the current location of the aircraft 102, the ending location of the flight path segment, and the midpoint of the flight path segment between the current aircraft location and the end of the flight path segment are each within the threshold distance or flight time of a potential diversion airport before including that particular potential diversion airport for further analysis.

In one or more embodiments, the threshold distance, flight time, or other filtering criteria are dynamically calculated or otherwise determined in real-time based on the current amount of fuel remaining onboard the aircraft, the current aircraft altitude, the current aircraft velocity, and the like, as well as accounting for current status information along the remainder of the flight path segment (e.g., meteorological conditions along the route, and the like). In this regard, the subset of potential diversion destinations to be analyzed with respect to the remainder of the current flight path segment ahead of the current aircraft location may be different from those that were included initially when the selection process 200 was performed on the ground due to changes that have occurred during flight, such that current status information associated with the aircraft 102 and/or the route is different from what was initially anticipated or expected prior to the aircraft 102 reaching or traversing the current segment, in conjunction with a reduced portion of the current flight path segment being considered due to preceding portions of the flight path segment having already been traversed by the aircraft 102.

After identifying the subset of airports to be analyzed with respect to the remainder of the current flight path segment, the diversion display process 400 receives or otherwise obtains current status information pertaining to the remaining airports to be analyzed, as well as potentially receiving or obtaining current status information pertaining to routes between the remainder of the flight path segment and any one or more of the airports being analyzed. The current status information pertaining to the airports generally represents the instantaneous, real-time or most recent available information that quantifies the current operations at the respective airports within the subset of potential diversion airports to be analyzed with respect to the current flight path segment. The current airport status information associated with a particular airport provides one or more base parameters for scoring or otherwise grading the viability of that airport with respect to one or more parameter groups, as described in greater detail below. For example, the processing system 108 may obtain, for each airport, one or more of the following: the current meteorological conditions at or near the airport, the current operational status of the runways and/or taxiways at the airport, the current air traffic conditions for the airport, any current auxiliary reports applicable to the airport (e.g., NOTAMs, PIREPs, SIGMETs, and the like), any current airspace restrictions, current meteorological forecast information for the geographic area encompassing the airport, and the like. Based on the current location of the aircraft 102, locations along the remainder of the flight path segment, and the respective locations of the airports being analyzed, the processing system 108 may also obtain current status information for potential routes from the current flight path segment to a particular airport, which also provides one or more base parameters for scoring or otherwise grading the viability of that airport with respect to one or more parameter groups, as described in greater detail below.

After identifying the subset of airports to be analyzed, the diversion display process 400 continues by ranking, prioritizing, or otherwise ordering the airports within the subset of airports relevant to the remainder flight path segment in terms of their relative viabilities with respect to the aircraft based on the current aircraft status information, the current airport status information, and the current route status information. In this regard, the potential diversion airports are scored and then ordered in terms of relative viability.

Thereafter, the diversion display process 400 continues by generating or otherwise providing graphical indication of the recommended diversion airport for the remainder of the current flight path segment (task 412). In some embodiments where a previously selected diversion airport is also the highest ranked or recommended diversion airport, the diversion display process 400 may display symbology on a navigational map for that airport along with additional graphical indicia (e.g., indicia 325) that notifies the pilot that the selected diversion airport for the current flight path segment is the recommended or optimal diversion airport. In some embodiments, in the absence of a previously selected diversion airport, the diversion display process 400 may similarly display symbology on a navigational map for that airport to notify the pilot of the recommended diversion airport, either with or without additional graphical indicia.

In one or more embodiments, when the previously selected diversion airport for the current flight path segment is not the highest ranked or recommended diversion airport for the remainder of the flight path segment, the diversion display process 400 may concurrently display symbology corresponding to the recommended diversion airport along with symbology for the selected diversion airport on the navigational map, with the symbology for the recommended diversion airport being rendered with a visually distinguishable characteristic or other graphical indicia that notifies the pilot of the existence of a potentially preferable diversion airport other than the selected diversion airport for the remainder of the current flight path segment. In one or more embodiments, the airport symbologies also provide graphical indicia of the parameter group states for both the recommended and selected diversion airports when displayed concurrently, thereby allowing the pilot to quickly ascertain any relative differences between the two airports. Additionally, one or more GUI elements may be provided on the navigational map display that are configured to allow the pilot or other user to modify the diversion airport associated with the current flight path segment, for example, by selecting the newly recommended diversion airport in lieu of the previously selected diversion airport for the segment. For example, in a similar manner as described above in the context of FIG. 3, a drop box or other GUI element (e.g., GUI element 330) may be presented that allows the pilot to drag and drop, select, or otherwise input the newly recommended diversion airport, and thereby modify the diversion airport associated with the current flight path segment. In response to identifying selection of the recommended diversion airport for the current flight path segment, the processing system 108 may automatically update the flight plan data maintained in the data storage element 124 to associate that airport with the current flight path segment.

The diversion display process 400 may periodically repeat to dynamically update the navigational map display to indicate the highest ranked diversion airport for the current flight path segment in real-time to reflect ongoing changes to aircraft status information, airport status information, route status information, and the like. Thus, when a selected or previously indicated diversion airport is believed to be

suboptimal, the pilot may be apprised of a potentially better available option, which, in turn, increases the pilot's situational awareness as well as improving the likelihood of successful operation of the aircraft **102** in the event of a diversion while flying the current flight path segment. Once the aircraft **102** traverses to the end of the current flight path segment or comes within a threshold distance or flight time of reaching the end of the segment based on the current aircraft status information, the diversion display process **400** is repeated for the next flight path segment of the flight plan until the aircraft **102** arrives at the final destination.

FIGS. 5-6 depict an exemplary sequence of navigational map displays **500** that may be displayed, rendered, or otherwise presented on the display device **104** in conjunction with the diversion display process **400** of FIG. 4 during flight. The navigational map **500** includes a graphical representation **302** of the flight plan overlaid or rendered on top of a background **304**, along with a graphical representation **502** of the aircraft **102** overlaid or rendered on top of a background **304**. In an exemplary embodiment, the navigational map **500** is associated with the movement of the aircraft **102**, and the aircraft symbology **502** refreshes or otherwise updates as the aircraft **102** travels, such that the graphical representation of the aircraft **502** is positioned over the terrain background **304** in a manner that accurately reflects the current (e.g., instantaneous or substantially real-time) real-world positioning of the aircraft **102** relative to the earth. The illustrated map **500** is centered on the flight plan **302**, where the aircraft symbology **502** is shown as traveling across the navigational map **300** (e.g., by updating the location of the aircraft symbology **502** with respect to the background **304**), while in other embodiments, the aircraft symbology **502** may be located at a fixed position on the navigational map **500** (e.g., by updating the background **304** and positioning of the flight plan **302** with respect to the aircraft graphic **502** such that the map **500** is maintained centered on and/or aligned with the aircraft graphic **502**). While the illustrated navigational map **500** is oriented in a cardinal direction, alternatively, the orientation of the navigational map **500** may be track-up or heading-up (i.e., aligned such that the aircraft symbology **502** is always traveling in an upward direction and the background **304** adjusted accordingly).

Referring to FIGS. 4-5, in response to obtaining the current location of the aircraft **102**, **502**, the processing system **108** identifies flight path segment **310** as the current flight path segment (e.g., tasks **402**, **404**) and graphically indicates or otherwise highlights the flight path segment **310** as the active flight path segment **310** for which one or more diversion airport(s) are being displayed. As described above, the processing system **108** identifies a subset of potential diversion airports satisfying one or more filtering criteria with respect to the remaining portion of the flight path segment **310** between the current location of the aircraft **102**, **502** and the end of the flight path segment **310** (e.g., the boundary with segment **312**), and then analyzes and ranks the relative viability of those airports with respect to the remaining portion of the flight path segment **310** (e.g., tasks **406**, **408**, **410**). In the illustrated embodiment, airport LKPL is identified as the highest ranked or recommended diversion airport for the current flight path segment **310**, and accordingly, the processing system **108** provides a graphical indication to the pilot, for example, by displaying symbology **504** representative of airport LKPL on the map **500** at the appropriate geographic location. For example, compared to the example presented in FIG. 3, during subsequent execution of the flight plan **302** at the time the aircraft **102** reaches

the starting point of the initial flight path segment **310**, airport LKPL may be more highly recommended than airport LKBP based on current status information deviating from what was initially forecasted or anticipated on the ground.

Still referring to FIG. 5, in exemplary embodiments, the processing system **108** also generates or otherwise provides a graphical element **506** that indicates the route from the current location of the aircraft **102**, **502** to the recommended diversion airport **504**, such as a line segment, arrow, pointer, or the like. Although not illustrated, in some embodiments, textual information may also be presented along the graphical element **506**, and such textual information associated with the graphical element **506** may include, for example, the bearing (or heading) for reaching the recommended diversion airport **504** from the current aircraft location, the distance between the current aircraft location and the recommended diversion airport **504**, one or more meteorological conditions associated with the route to the recommended diversion airport **504** (e.g., the wind speed), or the like.

Referring now to FIG. 6, and with reference to FIGS. 4-5, in exemplary embodiments, the diversion display process **400** is periodically performed to update the navigational map **500** as the aircraft **102**, **502** travels along the current flight path segment **310**. In this regard, in response to obtaining new or updated status information (e.g., task **402**), the graphical representation of the aircraft **502** is updated to maintain correspondence between the location of the aircraft graphic **502** with respect to the terrain background **304** and/or flight plan **302** and the real-world geographic location of the aircraft **102**. The diversion display process **400** then repeats the tasks of identifying flight path segment to be analyzed, identifying a subset of potential diversion airports satisfying one or more filtering criteria with respect to the remaining portion of the identified flight path segment, and then analyzing and ranking the relative viability of those airports with respect to the remaining portion of the flight path segment (e.g., tasks **404**, **406**, **408**, **410**). In this regard, the illustrated embodiment corresponds to a scenario where the highest ranked or recommended diversion airport for the remainder of the current flight path segment **310** is different from the previously selected diversion airport for the current flight path segment **310**. For example, based on changes to the status information associated with the aircraft, the potential diversion airports, the potential routes, or the like along with changes to the length of the remaining portion of the flight path segment **310** being analyzed, airport LKBP may subsequently be more highly ranked than airport LKPL with respect to the remaining portion of the current flight path segment **310** between the updated aircraft location and the end of the flight path segment **310**.

In the illustrated embodiment, airport LKBP is identified as the new highest ranked or recommended diversion airport for the current flight path segment **310**. For example, symbology **602** representative of airport LKBP may be displayed on the map **500** at the appropriate geographic location concurrently to displaying symbology **504** representative of the previously selected LKPL diversion airport, but with the newly recommended symbology **602** being rendered using one or more visually distinguishable characteristics different from symbology **504**. In this regard, the symbology **602** representative of a newly recommended but unselected diversion airport may be rendered with a transparency, fading, or other characteristic that deemphasizes the symbology **602** in a manner that indicates that the symbology

602 is not currently active or selected. That said, the symbology 602 may concurrently include one or more graphical indicia 625 indicating that the depicted airport is recommended without being selected or active. Additionally, in exemplary embodiments, the processing system 108 also generates or otherwise provides a graphical element 606 and associated textual information that indicates and characterizes the route from the current location of the aircraft 102, 502 to the recommended diversion airport 602.

In one or more embodiments, when multiple airport symbologies 504, 602 are presented on the map 500, the airport symbologies 504, 602 include graphical indicia representative of the parameter group viability states for the displayed airports 504, 602, thereby allowing the pilot to quickly ascertain the relative viability of the airports 504, 602 and make a more informed decision regarding which airport 504, 602 should be designated for use going forward. For example, in the illustrated embodiment of FIG. 6, the LKPL symbology 504 indicates one of the parameter groups associated with the LKPL airport does not have the highest viability level, whereas all of the parameter groups associated with the LKBP airport have the highest viability level. Thus, a pilot can quickly ascertain the relative deficiencies (if any) of the previously selected diversion airport with respect to the newly recommended diversion airport.

In response to identifying subsequent selection of the recommended diversion airport symbology 602 for use as the new diversion airport for the remainder of the current flight path segment 310, the processing system 108 may automatically update the flight plan data maintained in the data storage element 124 to associate the LKBP airport with the current flight path segment 310 in the event of a subsequent diversion. Additionally, in response to selection of the newly recommended LKBP airport for use instead of the LKPL airport, the LKBP airport symbology 602 may be updated and displayed using visually distinguishing characteristics indicating it is active and selected (e.g., by increasing transparency, reducing fading, etc.) and removing the LKPL airport symbology 504 from the navigational map 500.

Referring now to FIG. 7, in one exemplary embodiment, an airport ranking process 700 is performed in conjunction with the processes 200, 400 of FIGS. 2 and 4 to rank airports. The various tasks performed in connection with the illustrated process 700 may be implemented using hardware, firmware, software executed by processing circuitry, or any combination thereof. For illustrative purposes, the following description may refer to elements mentioned above in connection with FIG. 1. In practice, portions of the airport ranking process 700 may be performed by different elements of the system 100; however, for purposes of explanation, the airport ranking process 700 may be described herein primarily in the context of being performed by the processing system 108. Again, it should be appreciated that the airport ranking process 700 may include any number of additional or alternative tasks, may not be performed in the illustrated order, one or more of the tasks may be performed concurrently or omitted, and/or the airport ranking process 700 may be incorporated into a more comprehensive procedure or process having additional functionality not described in detail herein.

Referring to FIG. 7, and with continued reference to FIGS. 1-6, in exemplary embodiments, the airport ranking process 700 is performed whenever potential diversion airports are to be analyzed with respect to a particular flight path segment. The airport ranking process 700 receives or otherwise obtains current or anticipated status information

pertaining to the aircraft operation along the flight path segment of interest (task 702). In this regard, current aircraft status information may be utilized while en route and the aircraft is flying the segment of interest (e.g., during iterations of diversion display process 400) while anticipated aircraft status information is utilized for segments yet to be flown by the aircraft 102 (e.g., during iterations of the route diversion selection process 200). The aircraft status information provides one or more base parameters for scoring or otherwise grading the viability of an airport with respect to one or more parameter groups, as described in greater detail below.

Additionally, the airport ranking process 700 receives or otherwise obtains current or anticipated status information pertaining to the potential diversion airports to be analyzed (task 704). The airport status information quantifies the current or anticipated operations at the respective airports satisfying filtering criteria with respect to the flight path segment being analyzed by the respective process 200, 400. The airport status information associated with a particular airport provides one or more base parameters for scoring or otherwise grading the viability of that airport with respect to one or more parameter groups, as described in greater detail below. For example, the processing system 108 may obtain, for each airport, one or more of the following: the meteorological conditions at or near the airport, the operational status of the runways and/or taxiways at the airport, the air traffic conditions for the airport, any auxiliary reports applicable to the airport (e.g., NOTAMs, PIREPs, SIGMETs, and the like), any airspace restrictions, meteorological forecast information for the geographic area encompassing the airport, and the like.

The illustrated embodiment of the airport ranking process 700 also receives or otherwise obtains current or anticipated status information pertaining to routes between the current or anticipated location(s) of the aircraft along the flight path segment and any one or more of the airports being analyzed (task 706). In this regard, based on the geographic information defining the flight path segment and the respective locations of the airports being analyzed, the processing system 108 may identify or otherwise determine the waypoints or other intervening navigational reference points between locations along the flight path segment and a respective airport location that could be utilized to navigate to that airport location, or could otherwise be utilized to assess navigation to that airport location. In a similar manner, the processing system 108 then obtains, for each of the identified intervening navigational reference points, one or more of the following: the meteorological conditions at or near the navigational reference point, meteorological forecast information for the geographic area encompassing the navigational reference point, any auxiliary reports for a geographic area encompassing the navigational reference point, and the like. The status information associated with a particular navigational reference point or route to/from a particular airport provides one or more base parameters for scoring or otherwise grading the viability of that airport with respect to one or more parameter groups, as described in greater detail below.

After obtaining status information relevant to the aircraft and the airports to be analyzed, the airport ranking process 700 scores or otherwise grades each of the airports across a plurality of different parameter groups using the current status information pertaining to the respective airport and any applicable parameter weighting factors (task 708). As described in greater detail below in the context of FIG. 8, for each airport, status parameters associated with the aircraft

and the airport, along with any available status parameters associated with the route from the current aircraft location to the airport location, are classified or categorized into one of a plurality of parameter groups. In this regard, each parameter group generally represents a consolidation or integration of parameters that quantify a particular aspect of viably accessing or landing at an airport. For example, in the illustrated embodiment of FIG. 3, the parameter groups correspond to Aircraft Performance (e.g., parameters quantifying the ability of the aircraft to perform a landing at the airport), Airport Availability (e.g., parameters quantifying the ability of the airport to accommodate the aircraft), Weather (e.g., parameters quantifying potential meteorological impacts on traveling to and/or landing at the airport), and Airline Constraints (e.g., parameters quantifying other criteria or preferences pertaining to use of the airport). As another example embodiment, the parameters may be classified into one of the following groupings: an airport accessibility parameter group (e.g., en route weather, aircraft performance, fuel criteria, airspace restrictions, etc.), an airport availability parameter group (e.g., runway status, weather at the airport, air traffic at the airport, and the like), an aircraft configuration parameter group (e.g., type of aircraft, configurations or operating conditions of mechanical components, or the like), and an airline preferences parameter group (e.g., based on airline contracts with the airport, ground services at the airport, number of passengers onboard the aircraft, and the like). It should be noted that any number or type of parameter groups may be utilized to organize parameters influencing viability of landing at an airport, however, from a human factors perspective, consolidating the parameters into a relatively small number of parameter groups facilitates more expedient analysis by an aircraft operator. In this regard, fewer than four parameter groups could be utilized in some embodiments.

In addition to classifying the base parameters into parameter groups, exemplary embodiments also calculate or otherwise determine complex parameters derived based at least in part on one or more base parameters. For example, a runway viability parameter may be calculated for an active runway at a particular airport of interest based on the length of the runway, the current meteorological conditions at the airport, the current weight of the aircraft, and other parameters influencing the braking performance of the aircraft. In this regard, the processing system 108 may calculate the length required to stop the aircraft 102 based on the anticipated aircraft weight at the estimated time of arrival for the airport, the landing speed for the aircraft, and the anticipated surface conditions of the runway based on the current meteorological conditions at the airport. From there, the processing system 108 may determine a runway viability parameter value that quantifies the difference between the length required to stop the aircraft 102 and the runway length. The runway viability parameter value may then be classified into the appropriate parameter group for a given embodiment (e.g., Airport Availability). Again, it should be noted that any number or type of complex parameters may be calculated and classified into the appropriate parameter group.

Once the base and complex parameters for an airport are classified into the appropriate parameter groups, the processing system 108 determines a cumulative parameter group viability state and a cumulative parameter group viability score for each parameter group. In this regard, the cumulative parameter group viability score is determined based on the constituent parameters classified into that parameter group, with the cumulative parameter group

viability state being dictated by a binary parameter classified into the parameter group or the parameter group viability score, as described in greater detail below in the context of FIG. 8. Depending on the embodiment, the parameter group viability score may be calculated as a weighted combination of the constituent parameters, applying fuzzy logic to the constituent parameters, or a combination thereof. The parameter group viability states and scores for each airport are maintained in association with the airport.

After scoring the airports, the airport ranking process 700 classifies the airports into viability groups based on the scoring (task 710). In exemplary embodiments, the processing system 108 classifies the airports based on their respective parameter group viability states across all of the parameter groups, as described above. For example, airports having the highest parameter group viability state for each of the parameter groups may be classified into the highest viability airport grouping, airports having the lowest parameter group viability state for at least one of the parameter groups may be classified into the lowest viability airport grouping, with the remaining airports being classified into an intermediate viability airport grouping.

In the illustrated embodiment, the airport ranking process 700 scores or otherwise grades each of the airports based on their respective parameter group scores and then ranks each of the airports within their respective viability groups based on that scoring relative to others in that group (tasks 712, 714). In an exemplary embodiment, for each airport classified in the highest viability airport grouping, a cumulative viability score is calculated as a weighted combination of the individual parameter group scores associated with the airport. In this regard, weighting factors may be assigned by an airline operator, the pilot, or another individual to increase the influence of a particular parameter group score relative to the other parameter groups. For example, the viability score for the aircraft performance parameter group may be weighted more heavily than the airport availability parameter group viability score and the weather parameter group viability score, with the airline constraint parameter group viability score being weighted to have the least influence on the cumulative viability score. For other airport groupings, fuzzy logic and weighting factors may be applied to determine a cumulative viability score for each airport as some combination of its associated parameter group viability scores and its associated parameter group viability states other than those having the highest parameter group viability state. Within each grouping, the constituent airports are then sorted, ranked, or otherwise ordered based on their cumulative viability scores from most viable to least viable. In this manner, the airports are ranked primarily by viability groupings, and secondarily based on their cumulative viability scores relative to other airports within a particular viability grouping.

Referring now to FIG. 8, in one exemplary embodiment, a parameter group scoring process 800 is performed in conjunction with the airport ranking process 700 of FIG. 7 to score an airport across a plurality of parameter groups (e.g., task 708). The various tasks performed in connection with the illustrated process 800 may be implemented using hardware, firmware, software executed by processing circuitry, or any combination thereof. For illustrative purposes, the following description may refer to elements mentioned above in connection with FIG. 1. In practice, portions of the scoring process 800 may be performed by different elements of the system 100; however, for purposes of explanation, the scoring process 800 may be described herein primarily in the context of being performed by the processing system 108.

Again, it should be appreciated that the scoring process **800** may include any number of additional or alternative tasks, may not be performed in the illustrated order, one or more of the tasks may be performed concurrently or omitted, and/or the scoring process **800** may be incorporated into a more comprehensive procedure or process having additional functionality not described in detail herein.

The scoring process **800** may be performed any number of times in connection with the airport ranking process **700**, with each iteration of the scoring process **800** corresponding to an individual airport being analyzed for purposes of presentation in an intelligently ordered diversion list. In this regard, the scoring process **800** begins by receiving, obtaining, or otherwise identifying the base parameters pertinent to landing at the airport currently being analyzed, calculating or otherwise determining one or more complex parameters associated with the airport using one or more of the base parameters, and then dividing, categorizing, or otherwise classifying the base and complex parameters into their corresponding parameter groups (task **802**, **804**, **806**). In this regard, the processing system **108** obtains base parameters characterizing or quantifying the current or anticipated state of the aircraft **102**, the current or anticipated state of the airport being analyzed, and any current or anticipated status base parameters capable of characterizing or quantifying an anticipated route of travel between the flight path segment and the airport (e.g., tasks **702**, **704**, **706**). Thereafter, the processing system **108** calculates any complex parameters that can be derived from the available base parameters to further quantify or characterize the potential viability of landing at the airport. For example, as described above, a runway viability parameter for the airport may be calculated based on the length of an active runway at the airport (e.g., based on current status information for the airport indicating the runway is available for use), the current meteorological conditions at the airport, the current weight of the aircraft **102**, and other parameters influencing the braking performance of the aircraft **102**. As another example, calculation of aircraft range in the direction of a potential destination may entail calculating fuel consumption requirements based on the following base parameters: available fuel, route to destination (either direct or indirect depending on circumstances), meteorological parameters (e.g., tailwind component and the like), aircraft performance parameters (e.g., engine status and the like), which, in turn, may yield the maximum range towards the destination and fuel remaining at destination as two complex parameters. Additionally, the calculated amount of fuel remaining may be utilized to calculate other complex parameters, such as the aircraft weight at the destination, which may further be compared to maximum landing weight or other landing viability criteria for the particular destination. Thereafter, the base and complex parameters are assigned to or otherwise associated with a particular parameter group (e.g., an accessibility group, an availability parameter group, a meteorological parameter group, a preferences parameter group, or the like).

After the parameters for a particular airport have been classified into groups, the scoring process **800** proceeds by determining a viability state and score for each of the parameter groups (task **808**). The scoring process **800** first normalizes or otherwise converts each parameter within a parameter group to a common or universal scale to facilitate combining the parameters (task **810**). In this regard, based upon the particular data type associated with each parameter, its value is converted to a numerical representation on a scale in common with the other parameters in the group. For example, in one embodiment, three different parameter data

types are supported (e.g., binary, continuous, and discrete), and each parameter is normalized to a scale from 0 to 1, with 0 representing the lowest possible viability and 1 representing the highest possible viability. In such an embodiment, any parameters having a binary data type (e.g., where one potential value is viable and the other potential value(s) are not viable) associated therewith are then classified as either 0 or 1. Any parameters having a continuous data type are scaled to a value between 0 and 1, for example, by converting the parameter value to a ratio of the potential range of the continuous parameter (e.g., by dividing the parameter value by a maximum value for the parameter). Any parameters having a continuous data type are scaled to a value between 0 and 1, for example, by converting the parameter value to a ratio of the potential range of the continuous parameter (e.g., by dividing the parameter value by a maximum value for the parameter). Lastly, any parameters having a discrete data type are converted to a corresponding value between 0 and 1, for example, by using advance knowledge or expert judgment to assign a viability value between 0 and 1 to each potential discrete state for that parameter. For example, a runway surface condition parameter (which may be a complex parameter determined based on current or forecasted meteorological information for the airport location) may be quantified as follows: a clear or non-impacted surface condition state assigned a value of 1.0, a wet surface condition state assigned a value of 0.6, a snowy surface condition state assigned a value of 0.3, and an icy surface condition state assigned a value of 0.1.

Once the parameters of the group are on the same scale, exemplary embodiments of the scoring process **800** converts the value of each parameter to a corresponding viability state representation, combines the viability state representations of all the parameters of the group, and then converts that combined result to a corresponding parameter group score (tasks **812**, **814**, **816**). Fuzzy logic or a fuzzy regulator may be employed to convert the normalized parameter values into discrete viability states and then calculate the parameter group score as a weighted combination of the viability states (e.g., by multiplying or otherwise scaling the influence of each particular parameter using an associated parameter weighting factor). For example, each viability state may be represented by a state function placed at the normative value of the state (e.g. intermediate state placed at 0.5 with a triangular function showing pertinence to the state). The state functions for various states may overlap. A normalized value of a parameter is then represented by a sum of one or more state functions multiplied with respective relevance. The sum can then be weighted or scaled to adjust the influence of the parameter on the viability score. In this regard, the pilot, airline operator, or other user may tune the parameter group scoring in a desired manner to weight some parameters more heavily than others (otherwise, weighting factors for each parameter may be defaulted to the same value or unused). State functions of all parameters are then summed into the combined viability state. The combined viability state resulting from the weighted combination of individual parameter viability states is then converted to a corresponding parameter group score by defuzzification, for example, by taking the center of gravity (COG) of the combined viability state on a [0,1] interval. The position of the center of gravity then dictates one or more viability states with respective pertinence, and the most pertinent viability state is used as the parameter group score. The parameter group score is then stored or otherwise maintained in association with the airport and thereby numerically quan-

tifies or characterizes the relative viability of that aspect of landing at the airport (e.g., accessibility, availability, or the like).

The scoring process **800** also assigns or otherwise designates a viability state to each parameter group. In this regard, in the event the parameter group includes a binary parameter having a value (e.g., 0) that fails to satisfy an applicable criterion for landing the aircraft at an airport, the scoring process **800** automatically assigns or otherwise sets the parameter group state to the lowest viability state regardless of the parameter group score (tasks **818**, **820**). Conversely, when the parameter group does not include any binary parameters that fail applicable landing criteria, the scoring process **800** determines the parameter group viability state based on the parameter group score (task **822**), for example, by using fuzzy logic or a fuzzy regulator in a similar manner as described above (e.g., task **816**) to correlate the parameter group score to a viability state. The parameter group viability state and group viability score are also stored or otherwise maintained in association with the airport to quantify or characterize that aspect of landing at the airport in a discrete manner.

The loop defined by tasks **808**, **810**, **812**, **814**, **816**, **818**, **820** and **822** repeats for every parameter group associated with a particular airport. Thereafter, the parameter group viability states determined by the scoring process **800** and associated with that particular airport are then utilized to classify or otherwise order that airport into a particular viability grouping (e.g., task **710**), with the parameter group scores determined by the scoring process **800** and associated with that particular airport being utilized to determine a cumulative viability score and rank or otherwise order that airport within its viability grouping (e.g., tasks **712**, **714**). In this manner, the parameter group viability states are used to discretely categorize and order the airports at a relatively coarse granularity, and the parameter group viability scores are used to further order the airports with finer granularity. As a result, the task of resolving the particular nuances that may make one airport a better diversion destination than another airport having an identical viability state is offloaded from the pilot or other user.

By virtue of the subject matter described herein, the pilot or other vehicle operator can quickly ascertain the current (or real-time) qualitative viability of potential diversion destinations with respect to a particular discrete segment of travel, as well as the qualitative viability relative to other potential diversion destinations. Thus, the tasks of mentally or manually aggregating information for each individual destination (as well as the route thereto) from a variety of sources, determining any complex parameters for each individual destination, determining whether each individual destination satisfies any particular preferences, contractual agreements, or other ancillary requirements, and then assessing the relative viability or fitness of a particular destination with respect to the length of the segment of travel and relative to all of the other potential options is largely offloaded from the pilot or vehicle operator. Accordingly, the mental workload and stress is reduced (which helps to reduce any operator error), situational awareness is improved, and the time required to select an optimal diversion destination for a travel segment can be reduced.

For the sake of brevity, conventional techniques related to graphics and image processing, avionics systems, aircraft or airline operations, diversions, and other functional aspects of the systems (and the individual operating components of the systems) may not be described in detail herein. Furthermore, the connecting lines shown in the various figures contained

herein are intended to represent exemplary functional relationships and/or physical couplings between the various elements. It should be noted that many alternative or additional functional relationships or physical connections may be present in an embodiment of the subject matter.

The subject matter may be described herein in terms of functional and/or logical block components, and with reference to symbolic representations of operations, processing tasks, and functions that may be performed by various computing components or devices. It should be appreciated that the various block components shown in the figures may be realized by any number of hardware components configured to perform the specified functions. For example, an embodiment of a system or a component may employ various integrated circuit components, e.g., memory elements, digital signal processing elements, logic elements, look-up tables, or the like, which may carry out a variety of functions under the control of one or more microprocessors or other control devices. Furthermore, embodiments of the subject matter described herein can be stored on, encoded on, or otherwise embodied by any suitable non-transitory computer-readable medium as computer-executable instructions or data stored thereon that, when executed (e.g., by a processing system), facilitate the processes described above.

The foregoing description refers to elements or nodes or features being “coupled” together. As used herein, unless expressly stated otherwise, “coupled” means that one element/node/feature is directly or indirectly joined to (or directly or indirectly communicates with) another element/node/feature, and not necessarily mechanically. Thus, although the drawings may depict one exemplary arrangement of elements directly connected to one another, additional intervening elements, devices, features, or components may be present in an embodiment of the depicted subject matter. In addition, certain terminology may also be used herein for the purpose of reference only, and thus are not intended to be limiting.

The foregoing detailed description is merely exemplary in nature and is not intended to limit the subject matter of the application and uses thereof. Furthermore, there is no intention to be bound by any theory presented in the preceding background, brief summary, or the detailed description.

While at least one exemplary embodiment has been presented in the foregoing detailed description, it should be appreciated that a vast number of variations exist. It should also be appreciated that the exemplary embodiment or exemplary embodiments are only examples, and are not intended to limit the scope, applicability, or configuration of the subject matter in any way. Rather, the foregoing detailed description will provide those skilled in the art with a convenient road map for implementing an exemplary embodiment of the subject matter. It should be understood that various changes may be made in the function and arrangement of elements described in an exemplary embodiment without departing from the scope of the subject matter as set forth in the appended claims. Accordingly, details of the exemplary embodiments or other limitations described above should not be read into the claims absent a clear intention to the contrary.

What is claimed is:

1. A method of presenting potential diversion airports for an aircraft, the method comprising:

identifying, by a processing system, a flight path segment of a plurality of flight path segments between a departure location and a destination location based on a flight plan from the departure location to the destination location;

identifying, by the processing system, a subset of airports satisfying one or more filtering criteria with respect to the flight path segment;

obtaining, by the processing system, status information for each airport of the subset of airports from one or more external systems via a communications system onboard the aircraft;

obtaining, by the processing system, anticipated aircraft status information for each of a plurality of different locations along the flight path segment using one or more onboard systems;

for each respective airport of the subset:

determining, by the processing system, a respective viability score for each of the plurality of different locations along the flight path segment based at least in part on the respective status information for the respective airport of the subset and the respective anticipated aircraft status information for each of the plurality of different locations;

determining, by the processing system, a representative viability score for the respective airport with respect to a length of the flight path segment based on the respective viability scores for the different locations along the flight path segment;

identifying, from among the subset, a recommended diversion airport based on a ranking of respective airports of the subset of airports according to a respective representative viability score associated with each respective airport of the subset of airports; and

providing, by the processing system, an indication of the recommended diversion airport associated with the flight path segment on a display device onboard the aircraft.

2. The method of claim **1**, wherein providing the indication comprises displaying symbology representative of the recommended diversion airport on a map on the display device, wherein the symbology includes a graphical indication visually distinguishing the recommended diversion airport from one or more remaining airports of the subset concurrently displayed on the map.

3. The method of claim **1**, further comprising:

displaying a graphical representation of the aircraft on a map on the display device; and

displaying symbology representative of the recommended diversion airport on the map, wherein providing the indication comprises providing a graphical indication of a route from the graphical representation of the aircraft to the symbology representative of the recommended diversion airport.

4. The method of claim **1**, wherein determining the respective viability score comprises:

scoring the respective airport of the subset across a plurality of parameter groups using the respective anticipated aircraft status information associated with the aircraft for each of the plurality of different locations and the respective status information associated with the respective airport.

5. The method of claim **1**, further comprising:

determining, for each airport of the subset of airports, parameter group viability states for a plurality of parameter groups based at least in part on the respective anticipated aircraft status information for the aircraft for each of the plurality of different locations and the status information for that respective airport of the subset of airports, wherein the ranking is based on the parameter group viability states.

6. The method of claim **5**, further comprising providing, for each airport of the subset of airports, graphical indicia of the parameter group viability states associated with the respective airport of the subset of airports.

7. The method of claim **1**, further comprising dynamically updating the recommended diversion airport while the aircraft travels along the flight path segment.

8. The method of claim **1**, wherein identifying the subset of airports satisfying one or more filtering criteria with respect to the flight path segment comprises excluding one or more airports based on a distance from one or more locations along the flight path segment.

9. The method of claim **1**, wherein identifying the subset of airports satisfying one or more filtering criteria with respect to the flight path segment comprises excluding one or more airports based on a flight time from one or more locations along the flight path segment.

10. A non-transitory computer-readable medium having computer-executable instructions stored thereon that, when executed by the processing system onboard the aircraft, cause the processing system to perform the method of claim **1**.

11. A system comprising:

a display device onboard a vehicle;

a data storage element maintaining information defining a segment of a travel plan;

a communications system onboard the vehicle to obtain status information for each of a plurality of destinations from one or more external systems;

an onboard system to provide anticipated status information for each of a plurality of different locations along the segment of the travel plan; and

a processing system coupled to the communications system, the data storage element, the onboard system, and the display device to:

determine, for each of the plurality of destinations, a representative viability score with respect to a length of the segment associated with the respective destination of the plurality of destinations based on respective viability scores for each of the different locations along the segment determined based on at least in part on the status information for the respective destination and the anticipated status information for each of the plurality of different locations along the segment of the travel plan;

identify a recommended diversion destination from among the plurality based on a ranking of the respective destinations according to the respective representative viability scores for each of the plurality of destinations; and

provide an indication of the recommended diversion destination associated with the segment on the display device.

12. A method of presenting potential diversion destinations for a vehicle, the method comprising:

identifying, by a processing system onboard the vehicle, a segment of a plurality of segments of a route between a departure location and a destination location;

obtaining, by the processing system, current status information associated with the vehicle traveling along the segment from one or more onboard systems;

obtaining, by the processing system, anticipated status information associated with a plurality of different locations along the segment;

obtaining, by the processing system, status information associated with each of the plurality of alternate destinations;

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for each of the plurality of alternate destinations:

determining, by the processing system, a respective viability score for each of the plurality of different locations along the segment based at least in part on the current status information, the respective status information associated with the respective alternate destination, and the respective anticipated status information for each of the plurality of different locations;

determining, by the processing system, a representative viability score for the respective alternate destination with respect to a length of the segment based on the respective viability scores for the plurality of different locations along the segment;

identifying, by the processing system, a recommended alternate from among the plurality of alternate destinations based on a ranking of respective alternate destinations according to the respective representative viability scores associated with the respective alternate destinations; and

providing, by the processing system on a display device onboard the vehicle, an indication of the recommended alternate associated with the segment.

13. The method of claim **12**, further comprising:

dynamically determining, by the processing system, updated representative viability scores for each of the plurality of alternate destinations;

identifying, by the processing system, an updated recommended alternate from among the plurality of alternate destinations based on a ranking of respective alternate destinations according to the updated representative viability stores associated with the respective alternate destinations; and

providing, by the processing system on the display device, a second indication of the updated recommended alternate associated with the segment.

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14. The method of claim **12**, wherein providing the indication comprises displaying symbology representative of the recommended alternate using one or more visually distinguishable characteristics different from symbology representative of a previously selected alternate associated with the segment.

15. The method of claim **1**, wherein the one or more onboard systems comprise a flight management system.

16. The method of claim **1**, wherein the one or more external systems comprise an external weather monitoring system.

17. The method of claim **1**, wherein the one or more onboard systems include at least one of: a weather system, an air traffic management system, a radar system, a traffic avoidance system, an autopilot system, an autothrust system, a flight control system, a hydraulic system, a pneumatic system, an environmental system, an electrical system, an engine system, a trim system, a lighting system, a crew alerting system, an electronic checklist system, and an electronic flight bag.

18. The method of claim **1**, wherein the one or more onboard systems comprise a weather radar system.

19. The method of claim **1**, further comprising graphically indicating the flight path segment on a map displayed on the display device, wherein:

providing the indication comprises displaying symbology representative of the recommended diversion airport on the map on the display device; and

the symbology visually distinguishes the recommended diversion airport from one or more remaining airports of the subset concurrently displayed on the map.

20. The system of claim **11**, wherein the vehicle comprises an aircraft and the onboard system comprises a flight management system.

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